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# PROBABILITY DISTRIBUTIONS OF ALTITUDE DEVIATIONS

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# Probability Distributions of Altitude Deviations

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Space Administration

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## EXECUTIVE SUMMARY

Aircraft flying at altitudes different from those assigned by Air Traffic Control (ATC), are frequently reported to the Aviation Safety Reporting System (ASRS). This study focuses on the probability distributions of the magnitudes of altitude deviations obtained from 502 ASRS reports received between May, 1978 and November, 1979, and the implications of those distributions.

The altitude deviations range from 100 to 16,500 feet, and occur with nearly equal frequencies above and below assigned altitudes. A scatterplot shows that large and small altitude deviations are not strongly associated with high and low altitudes, respectively. The magnitudes of the altitude deviations show marked concentrations at integer multiples of 1,000 feet. Less than 20 percent of this concentration is attributed to rounding. Rather, the concentrations reflect the tendency of deviating aircraft to be flying level at cardinal altitudes or for their deviation to be detected at cardinal altitudes. For approximately 100 reports involving conflicts where avoidance or evasive action was taken, a scatterplot shows that large altitude deviations are not associated with small miss distances.

The magnitudes of altitude deviations, without regard to sign, are found to be exponentially distributed with a mean altitude deviation of approximately 1,080 feet. Exponential distributions are also found for various subgroups of the reports that include: failures-to-maintain assigned altitudes, including premature departures; and failures-to-attain assigned altitudes, including failures to meet crossing restrictions. The exponential distributions of the altitude deviations for these subgroups have mean altitude deviations of 770, 1,240, and 1,960 feet, respectively. Exponential distributions of altitude deviations are also obtained for other subgroups that include: reports involving pilot-initiated and controller-directed evasive actions, reports received from pilots, reports received from controllers, and reports involving military and nonmilitary aircraft.

The exponential form of the distribution of magnitudes of altitude deviations is explained by interpreting the results in a time domain. If the magnitude of an altitude deviation is divided by a reference rate of climb or descent, the resulting time can be interpreted as an estimate of the time required to generate the altitude deviation at that rate. Because altitude control mechanisms were inoperative, overriden, or failed to serve their function in most narrative accounts of altitude deviations, such a time is interpreted as referring to the time required for human detection of the altitude deviation. The exponential forms for the detection times are also implied by a direct argument given in the report.

Based on an assumed reference rate of 1,500 ft/min, it is computed that half of the time an altitude deviation would be detected within 30 seconds. Corresponding half-lives for altitude deviations involving failures-to-level, failures-to-maintain, and failures-to-attain are approximately 20, 35, and 55 seconds, respectively. A change in the reference rate of climb or descent yields an inversely proportional change in mean detection time but does not change the exponential form of the distribution of detection times. A reference rate of 1,500 ft/min is used for illustrative purposes only.

The general argument for exponentially distributed detection times may be applicable to a variety of other aviation safety problems. For the argument to be applicable, the problem must come into existence at some inception time and then persist until detection. Problems involving heading errors and communication errors are likely candidates for exponential distributions of detection times; less likely candidates include problems associated with fatigue or inexperience.

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# PROBABILITY DISTRIBUTIONS OF ALTITUDE DEVIATIONS

by

Ralph E. Thomas* and Loren J. Rosenthal**

## SUMMARY

This is a statistical study of the magnitudes of altitude deviations obtained from 502 ASRS reports received between May, 1978 and November, 1979. The deviations range from 100 to 16,500 ft. The magnitudes of altitude deviations, without regard to sign, are found to be exponentially distributed with a mean of 1080 ft. Exponential distributions are also found for various subgroups of the reports that include: failures-to-level in which pilots fail to level at assigned altitudes; failures-to-maintain assigned altitudes, including premature departures; and failures-to-attain assigned altitudes, including failures to meet crossing restrictions. These subgroups show mean altitude deviations of 770, 1240, and 1960 ft, respectively. At a constant reference rate of climb or descent, these results are interpreted as exponential distributions of times required for human detection of altitude deviations. On this basis, at an assumed reference rate of 1500 ft/min, it is computed that, half of the time, an altitude deviation would be detected within 30 seconds. Corresponding half-lives of altitude deviations involving failures-to-level, failures-to-maintain, and failures-to-attain are found to be approximately 20, 35, and 55 seconds, respectively. A change in the reference rate of climb or descent yields a change in the mean detection time, but does not change the exponential form of the distribution of detection times.

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## INTRODUCTION

Altitude deviations are one of the most frequent aviation safety problems reported to the Aviation Safety Reporting System (ASRS). This study examines the probability distributions of the magnitudes of altitude deviations and their implications. It is based on an analysis of 805 reports received between May, 1978 and November, 1979. Altitude deviation data were obtained from 502 of the reports.

## OBJECTIVES AND SCOPE

The objective of this research is to identify and describe the statistical properties of the magnitudes of the altitude deviations reported to the ASRS. In this report, an altitude deviation is said to occur when an aircraft is flown at an altitude different from that assigned by ATC. This definition excludes from study those instances in which (1) aircraft were flown at improper altitudes because of controller errors, (2) aircraft climbed or descended from previously assigned to newly assigned altitudes, and (3) altitude excursions resulted from the exercise of pilot emergency authority. The research includes reports involving climbing or descending aircraft that fail to level at the ATC assigned altitude, reports in which an aircraft prematurely leaves an ATC assigned altitude, and reports in which an aircraft fails to reach its assigned altitude. These are termed in this report, respectively, failures-to-level, failures-to-maintain, and failures-to-attain.

Initial research efforts analyzed altitude deviations as spatial phenomena. ASRS incident reports are generally conducive to such an analysis and provide sufficient data to estimate the magnitude of the deviation in distance units.

As the research effort evolved, it became apparent that the altitude deviations might usefully be examined in the time domain as well. The statistical properties of the detection times of altitude deviations are of particular interest. The data provided in ASRS reports generally are insufficient to directly measure the magnitudes of altitude deviations in time. However, some broad inferences can be drawn in the time domain using deviation distance measures as surrogate data.

The flight geometry of altitude deviations is not as simple as might be imagined. The three basic altitude deviations cited above have varying spatial and temporal characteristics. During the study effort, the geometry of altitude deviations was investigated carefully. This exercise served two purposes: (1) it provided a basis for explicitly defining alternative altitude deviation measures in both the spatial and the time domain, and (2) it permitted the authors to code the actual flight pattern of each altitude deviation in terms of a standardized geometric form and to contrast that with a coded version of the expected flight pattern anticipated by ATC.

The statistical part of this study is directed toward characterizing the distributional properties of altitude deviations including the form and parameters of the distributions and their interpretations. Later it will be evidenced that the altitude deviations reported to ASRS are amenable to study as exponentially distributed populations. Considerable attention is given to partitioning the population in a search for statistically distinct subpopulations.

## APPROACH

The research approach is detailed in terms of: (1) the geometry of altitude deviations, (2) the method used to compute the magnitude of deviations, (3) the interpretation of the computed deviations in the spatial domain, (4) the reinterpretation of the computed deviation in the time domain, (5) the data content of ASRS altitude deviation reports, and (6) the variables used to partition the data during the search for subpopulations.

### The Flight Pattern Geometry of Altitude Deviations

Definitions. - Altitude deviation flight patterns are the deviating aircraft's flight characteristics at two points during the incident. These two points are called the inception and emergence points. The inception point is the first in space and time where an altitude deviation can be observed or predicted with certainty by a knowledgeable observer. Accordingly, the inception point corresponds to the first point at which the aircraft is either in a deviant state; or, it represents a preceding point at which the aircraft's flight dynamics necessitate a subsequent altitude excursion.

The emergence point is the first point where an aircraft's actual flight altitude differs from the level flight altitude expected by ATC. The ATC expected level flight altitude is based upon ATC's expectation that an aircraft which receives an altitude assignment will (1) depart for the assigned altitude in a timely fashion, (2) ascend or descend to the assigned altitude at a rate consistent with ATC's understanding of its performance characteristics, (3) level at its assigned altitude upon reaching it, and (4) maintain the assigned altitude until cleared or directed to another altitude.

Flight pattern coding scheme. - The altitude deviations investigated are coded in terms of their flight characteristics at the inception and emergence points. Specifically, an altitude deviation consists of four phases:

I1 = The flight phase immediately before the inception point
I2 = The flight phase immediately after the inception point
E1 = The flight phase immediately before the emergence point
E2 = The flight phase immediately after the emergence point.

In each flight phase the aircraft would be in one of the following states:

1. Level Flight (L)
2. Ascending Flight (A)
3. Descending Flight (D)
4. Transition to Level Flight (TL)
5. Transition to Ascending Flight (TA)
6. Transition to Descending Flight (TD).

Each aircraft's flight pattern is coded for the four flight phases using the following format: I1/I2, E1/E2. The definitions and coding scheme are illustrated for selected flight patterns in Figure 1 depicting the three basic altitude deviation flight patterns:

1. Failures-to-level at assigned altitudes including all flight patterns where the aircraft reaches its assigned altitude and flies through it without levelling
2. Failures-to-maintain assigned altitudes including all flight patterns where the aircraft departs or drifts from an assigned altitude where it had been flying level
3. Failures-to-attain assigned altitudes including all cases where the deviating aircraft fails to reach its assigned altitude in a timely fashion.

Variations on these fight patterns are possible, but the categories are mutually exclusive and exhaustive. Each deviation can be placed in one, but only one, of these categories.

Associated with each illustration in Figure 1 are the codes corresponding to the actual aircraft flight pattern and the ATC expected flight pattern. Together they provide a standardized geometric description of the altitude deviation.

Figure 1a shows an ascending failure-to-level that is designated A/A, A/A. This is interpreted as when an ascending aircraft approaches its assigned altitude and should have commenced levelling no later than the deviation's inception point, but instead, it continues to ascend. This is denoted as A/A. At this point the pilot-not-flying or other observer could have predicted the subsequent deviation if they were watching. As the aircraft reached its assigned altitude it was still ascending and continued to ascend thereafter. The deviation emerges at this point. This is also coded A/A. The total flight pattern then becomes A/A, A/A. By contrast, the flight pattern expected by ATC is: A/TL, TL/L denoting ascent followed by transition to level flight at the assigned altitude.

A failure-to-maintain deviation with a flight pattern code L/TD, L/TD is shown in Figure 1b. This incident might involve a level flying aircraft that

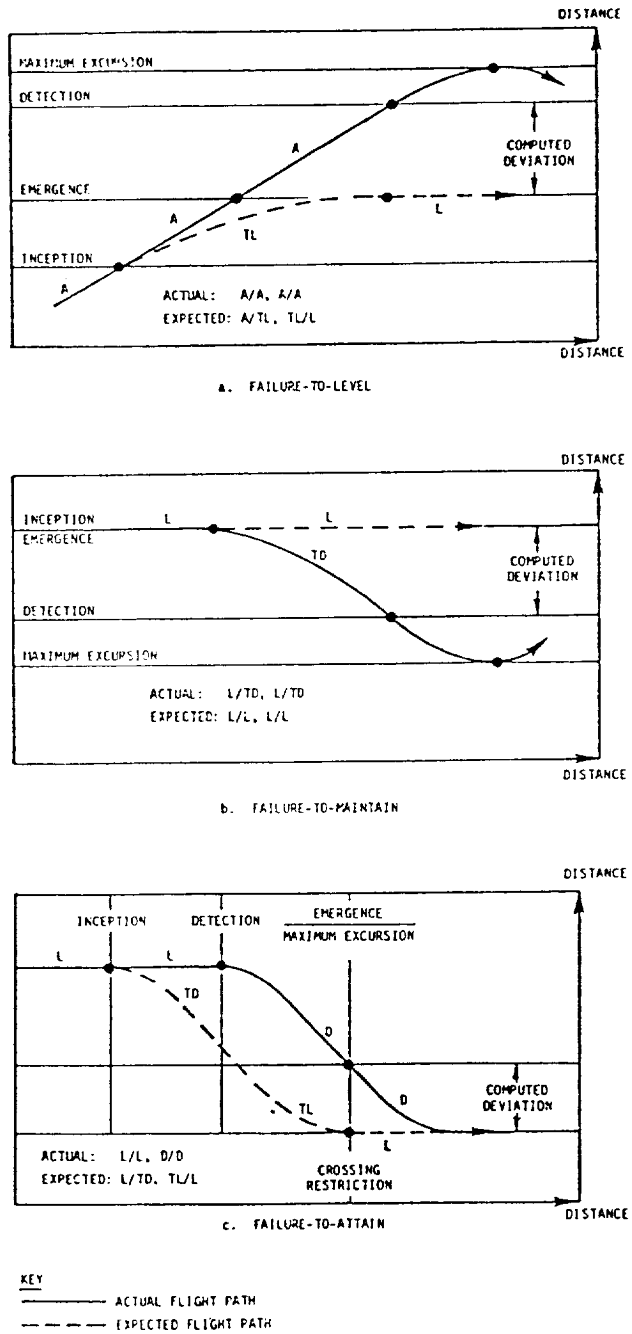


FIGURE 1. THE GEOMETRY OF ALTITUDE DEVIATIONS

mistakes another aircraft's clearance as its own and descends without authorization. This deviation would be identifiable at the beginning of the excursion but not before. Thus, the inception and emergence points of this and all failures-to-maintain are simultaneous. The flight pattern denoting this repeats itself: L/TD, L/TD. The ATC expected flight path for this incident is L/L, L/L requiring the maintenance of level flight.

A failure-to-attain incident of the L/L, D/D variety is depicted in Figure 1c. Such an incident involves an aircraft that belatedly descends to meet a crossing restriction. The inception point is the last point where the aircraft could have departed from the higher altitude and still met the crossing restriction. In this incident the aircraft remains level after the inception point, making the deviation inevitable and predictable. This is coded L/L. Assuming that the failure is detected and the aircraft makes a belated descent before the crossing restriction is encountered, the aircraft would descend at the emergence point -- in fact, the crossing point. This is coded D/D and the entire code then becomes L/L, D/D. The contrasting ATC expected flight pattern is L/TD, TL/L denoting level flight with transition to descent at the inception point followed by transition to level flight before the crossing point with level flight thereafter.

Every altitude deviation in the database has a detection point subsequent to the inception point. Further, the detection point usually but not always follows the emergence of the deviation. (Some of the failure-to-attain incidents involving crossing restrictions have detection points preceding the emergence of the deviation.)

The flight state at the detection point is generally the same as the deviating aircraft's flight state immediately following the emergence point. However, this is not true for a few incidents. These incidents involve aircraft flying through or departing from an assigned altitude and levelling afterwards at an unassigned altitude where they fly for some time before the deviation is detected.

## Computing the Deviation

The ASRS narratives in this study generally mention two altitudes: (1) the ATC assigned altitude, and (2) a different altitude where the aircraft actually flew. Most frequently the second altitude is the aircraft's altitude at the time the deviation was detected. In a few reports it is the maximum excursion point of the aircraft or some other altitude at which the aircraft flew subsequent to the deviation's inception.

In this study the magnitude of each altitude deviation is computed as the absolute value of the difference between the ATC assigned altitude and a different, actual flight altitude. Deviations measured in this manner are amenable to analysis and yield statistically meaningful results.

The magnitudes of the deviations in 502 out of 805 incidents in the database are measured in this way. Twenty-nine reports are excluded because of unresolvable conflicts within the narratives as to the actual deviations. An additional six reported deviations are excluded as outliers whose magnitudes far exceeded these of other reports. These are discussed more thoroughly later. Deviation distances are not computed for the remaining 268 reports for one or more reasons: (1) the incident is not clearly identifiable as an altitude deviation, (2) the data are insufficient to compute a deviation, or (3) the report describes an incident already in the database. The last occurs when two or more individuals independently report the same incident to ASRS.

Interpretation in the spatial domain. - The deviations computed in this study generally describe the vertical altitude differential between the ATC assigned altitude and the actual flight altitude at the detection point. Accordingly, the computed deviation can usually be regarded as a lower bound measure of the maximum excursion distance during the deviation. This concept is made clear in Figure 2 using a failure-to-level incident to illustrate the computed deviation measurement and its relationship to the maximum altitude excursion distance.

Reinterpretation in the time domain. - It is possible to reinterpret the computed deviations in the time domain using the computed deviation distance as a proxy for the deviation time. This is reasonable because there is a rough proportionality between the time that elapses during an altitude deviation incident and the distance which the aircraft covers during the incident.

In the time domain, an interesting measure is the time elapsed between the inception of an incident and its detection. The computed deviation distance can be used to develop a lower bound approximation of this detection time. Specifically, if one knows the average vertical speed of the aircraft during the deviation, it is possible to calculate the time elapsed between the emergence of a deviation and its detection. This is a lower-bound estimate for the time that elapsed between the deviation's inception and detection. This latter quantity is meaningful because the inception point is the first point where the deviation is capable of detection. These concepts are illustrated in Figure 3 by reinterpreting a computed deviation distance for a failure-to-level incident in the time domain.

## Data Content of Narratives

The narrative portion of each ASRS report was examined to extract quantitative information about the magnitude of the altitude deviation, and to classify the report according to the flight patterns just described. Example narratives are given in Table 1. The first three narratives are based on pilot reports; the last two narratives were submitted by controllers. Underscoring indicates the altitude information used to compute the altitude deviation.

The failure-to-level narrative shows that the difference between the flight altitude and the assigned altitude is 1000 ft. This altitude deviation is judged to underestimate the maximum excursion distance. Similarly, an altitude deviation of 1200 ft is obtained for the failure-to-maintain example. This deviation is also judged to be an underestimate of the maximum altitude deviation. In the third example, a failure-to-attain incident report provides data used to compute an altitude deviation of 2000 ft. This

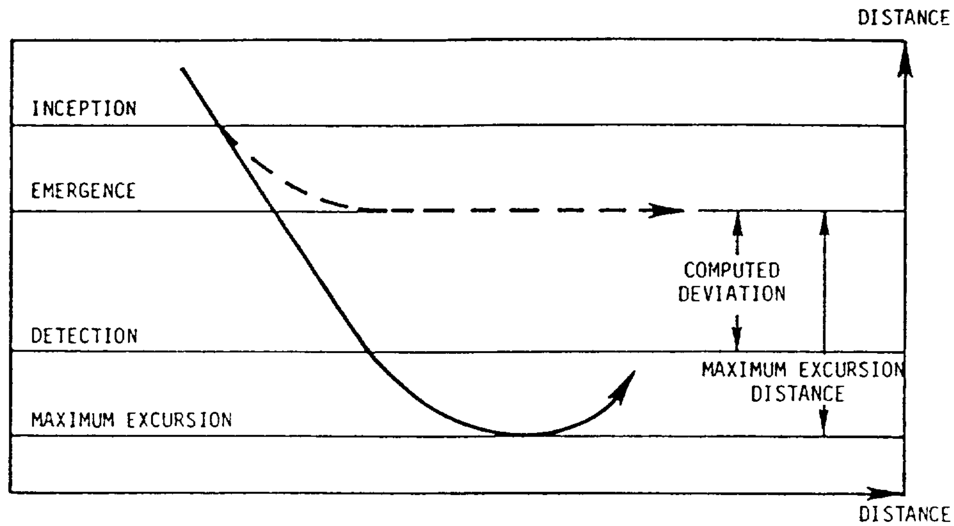


FIGURE 2. COMPUTED DEVIATION INTERPRETED IN THE SPATIAL DOMAIN FOR A FAILURE-TO-LEVEL

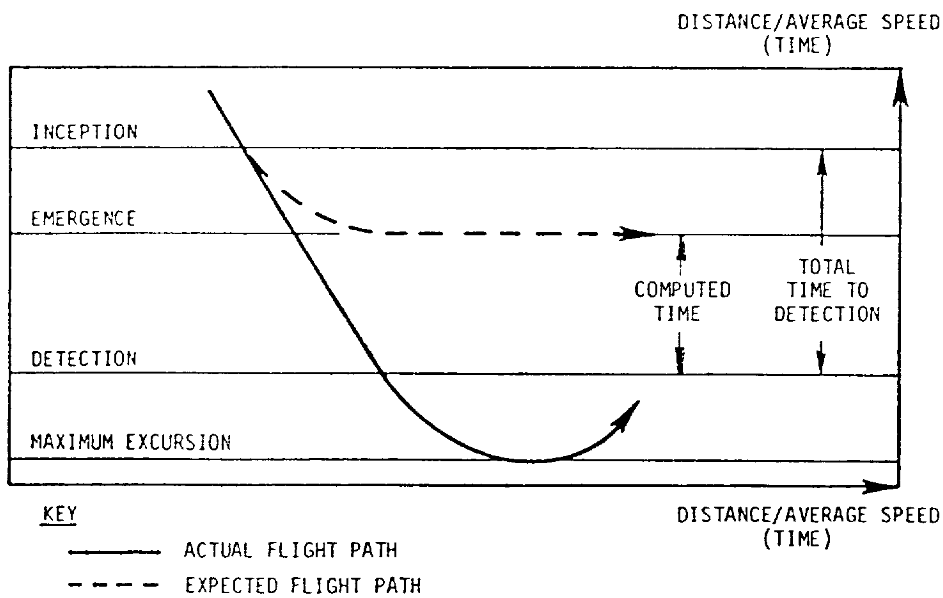


FIGURE 3. COMPUTED DEVIATION REINTERPRETED IN THE TIME DOMAIN FOR A FAILURE-TO-LEVEL

## TABLE 1. EXAMPLE NARRATIVES FROM ASRS REPORTS INVOLVING ALTITUDE DEVIATIONS

| Accession Number | Narrative |
|---|---|
| | (a) Example of a Failure-to-Level Narrative |
| 15528 | NARRATIVE: While climbing to FL190, reassigned to FL250. Requested FL270 at which time the altitude alert was inadvertently set to FL270. The person flying thought FL270 was assigned. As FL260 was reached Center asked altitude. They were told and then replied FL250 was assigned. We descended back to FL250. The situation occurred because of a misunderstanding between crew members and Center. However the crews using altitude alert systems get programmed to listen for the aural warning and have a tendency to not pay close attention to altitudes. |
| | (b) Example of Failure-to-Maintain Assigned Altitude |
| 10529 | NARRATIVE: Received a call from Center advising that our 9000 ft FL would not be sufficient after AVE, which we were aware of. They asked if we would like 11000 or 13000. We acknowledged we would take 11000. Ctr in turn said, I believe, ACFT ABC cleared to 11000. We in turn replied, ACFT ABC is out of 9000 for 11000. Another aircraft, ACFT CBA, at the same time received a climb to 13000. When I was at 10200 Ctr called and asked if I was climbing. I replied I was and Center said that he had not given me climb clearance. I replied that I thought I had received it and that I had replied at least twice to him that I was climbing. I even discussed the situation with my co-pilot and we were in agreement. Ctr did say there was no problem caused and that we could continue to 11000. Possibly the nearness of these two numbers caused either myself or Ctr some confusion. I personally will be more diligent myself in the future. |
| | (c) Example of Failure-to-Attain Assigned Altitude |
| 13727 | NARRATIVE: The 8000 ft crossing altitude at Falon was moderately missed. ATC told us about it and we descended to 8000. (There was no problem with other traffic or anything else. We had stayed at 10,000 ft, 250K from FTZ). The main reason for the missed altitude is that I overlooked the 8000 ft requirement when I initially looked at the descent profile chart. Then I had that part of the chart covered with a piece of scrap paper to copy frequencies and failed to look again. The co-pilot was flying and had flown the route all month. However, during the course of the descent we had been vectored off route thus canceling the profile descent and recleared to maintain 12,000 versus 10,000. Then had been cleared via profile descent route to 12R. This meant to me via FTZ to Falon but not below 12,000. I later questioned approach control on this and they cleared us via profile descent to 12R. Some discussion arose in the cockpit concerning the legality of all this being recleared, etc. and as a result the co-pilot forgot to descend to cross Falon at 8000. To me these profile descents are full of traps like this and I would much prefer not to have them. |
| | (d) Example Narrative with Insufficient Altitude Information |
| 15386 | NARRATIVE: On 7/79 Wed. I was the radar controller on HCH MT JAKE05, and F4 ACFT A based at MEI was cleared by BHM APCH for entry IR069. At the completion of his route JAKE05 reported to me for clearance back to MEI. JAKE05 stated that he was at the HCH340 008 at 2500 MSL, contrary to his altitude profile and infringing on IFR approaches to CSV. The pilot was unaware of his required altitude restrictions. This is the third such operation I have been involved in since IR069 has been designed, all involving the same pilot deviation. |
| | (e) Narrative not Classifiable by Flight Pattern |
| 15391 | NARRATIVE: ACFT A was cleared to the Budat intersection to hold at 5000 ft. ACFT B was cleared to the Austin 21 DME on the 230 degree radial to hold at 3000. This was done at approximately (a given time). Shortly thereafter A asked if there was a twin type ACFT holding in his area. I told A that there was but that he was at 3000 ft. A then informed me that he was at 3000 ft. |

altitude deviation is judged to be a maximum altitude excursion. In the fourth narrative, the flight altitude is 2500 MSL, but, the assigned altitude is not reported. This narrative is an example of the altitude deviation reports for which the magnitude of the deviation could not be computed.

The first example in Table 1 involves an aircraft that was 2000 ft below its assigned altitude, so the altitude deviation is taken to be minus 2000 ft. However, there is insufficient information in the report to classify it as one of the flight pattern categories. The report exemplifies 122 of the 502 reports that provide information on altitude deviations but cannot be further classified according to flight pattern.

In summary, the approach used in this study involves examining 805 narratives to identify 502 reports containing altitude deviation information. This group of 502 deviations is studied to determine its statistical properties. The group is then partitioned into a variety of subgroups to determine whether the statistical properties of the altitude deviations differ markedly from one subgroup to another.

## Partitioning the Population

During the study effort, the authors considered the possibility that the 502 reports contained in the database could be partitioned into subpopulations that differed statistically as to either their distributional forms or parameters. One obvious partition is by flight pattern: failures-to-level, versus failures-to-maintain, versus failures-to-attain, versus unclassifiable. Other partitions investigated include:

- Pilot versus controller versus pilot and controller reports*
- Military aircraft involvement versus no military involvement
- Conflict, evasive action taken or no time versus conflict, no known evasive action taken versus no conflict requiring evasive action.

*Incidents where a pilot and a controller independently report the same incident.

Findings are presented in this study in terms of the above partitions and for the population as a whole.

## RESULTS

### Distribution of Altitude Deviations

Signs of deviations. - An altitude deviation is taken to be negative when the aircraft is flown below the assigned altitude; positive when the aircraft is flown above the assigned altitude. Among the 502 altitude deviations, 261 (52 percent) are positive; 241 (48 percent) are negative. Although more positive than negative deviations are reported, the difference can be attributed to chance. Thus, it is concluded that positive and negative altitude deviations occur with approximately equal frequencies.

Moreover, a graphical examination shows that the magnitudes of the positive and negative deviations are generally symmetric about the origin. Based on these findings, subsequent examinations of altitude deviations are made without regard to sign.

Outlying altitude deviations. - All but six altitude deviations lie in the range from 100 to 6000 ft. The six exceptionally large altitude deviations are listed in Table 2. Because of the sensitivity of statistical calculations to such outliers, these six are excluded from subsequent analyses.

Although the basis for excluding the outliers is computational, there are additional grounds for segregating them from the other altitude deviation reports. Four of the six (1, 4, 5, and 6) involve deviations where the final magnitude of the excursion greatly exceeded its magnitude at the point of detection. The deviations became larger because of mechanical malfunctions impeding the reassertion of control or because of the pilot's decision to deviate from ATC directives. By contrast, most of the 502 computed deviations measure the magnitude of the deviation as the difference between the assigned altitude and the flight altitude at -- not after -- the detection time.

TABLE 2. LARGE ALTITUDE DEVIATIONS EXCLUDED FROM SUBSEQUENT ANALYSES

| Number | Altitude Deviation, feet | Number of Reports | Comments Based on Narratives * |
|---|---|---|---|
| (1) | 7,000 | 1 | • Aircraft stalled because of wing icing; dropped from 33,000 feet to 26,000 feet before recovering. (11395) |
| (2) | 10,000 | 2 | • Failure to meet crossing restriction due to crew complacency and misreading of altimeters. (10088) |
| (3) | 10,000 | | • Failure to meet crossing restriction due to misunderstood clearance. (10916) |
| (4) | 11,000 | 1 | • Descended without authorization from 24,000 feet to 13,000 feet; radio communication with ATC, which had detected deviation, was disrupted. (11046) |
| (5) | 13,000 | 1 | • Descended without authorization from 35,000 feet to 22,000 feet after cancelling IFR in an area restricted to IFR traffic. (10991) |
| (6) | 16,500 | 1 | • Military aircraft lost its heater during refueling and descended from 26,000 feet to 9,500 feet without clearance. (14312) |
| | Total | 6 | |

* Numbers in parentheses indicate ASRS accession numbers.

Exponential distribution of the altitude deviations. - The lower portion of Figure 4 is a histogram of the 502 altitude deviations that range from 100 to 6000 ft. The histogram shows sharp peaks at integer multiples of 1000 ft. Secondary peaks are shown at 500, 1500, and 2500 ft. The smooth curve fitted to the data represents an exponential distribution with a mean altitude deviation of 1080 ft.

The fitted exponential distribution provides estimates of the expected number of reports at each altitude deviation. With this interpretation, more reports than expected are shown at multiples of 1000 ft, and fewer reports than expected are shown at most deviations measured in hundreds of feet. These discrepancies are not due to rounding. This finding is discussed in more detail later in this section and in Appendix A to this report.

The upper portion of Figure 4 shows a linearizing transformation for the cumulative form of the fitted exponential distribution. The data points are grouped into relatively disconnected sets corresponding to the 1000-ft intervals. The sharp discontinuities at the 1000-ft intervals reflect the concentrations of data at these points. If the data were perfectly exponentially distributed, the data points would fall exactly on the fitted straight line shown in the figure. This is shown in the mathematical derivations in Appendix C. To the extent permitted by the discontinuities at the 1000-ft intervals, the fitted straight line provides a good fit to the data. It is concluded that the set of 502 altitude deviations is well-approximated by an exponential distribution.

## Analysis of Subgroups

To obtain a more detailed understanding of the database it was repeatedly partitioned into subgroups, separately analyzed, and compared. Attention focused on determining whether (1) the means of the subpopulation distributions were similar, and (2) the individual subgroups were exponentially distributed, like the overall population.

The population was partitioned into the following subgroups:

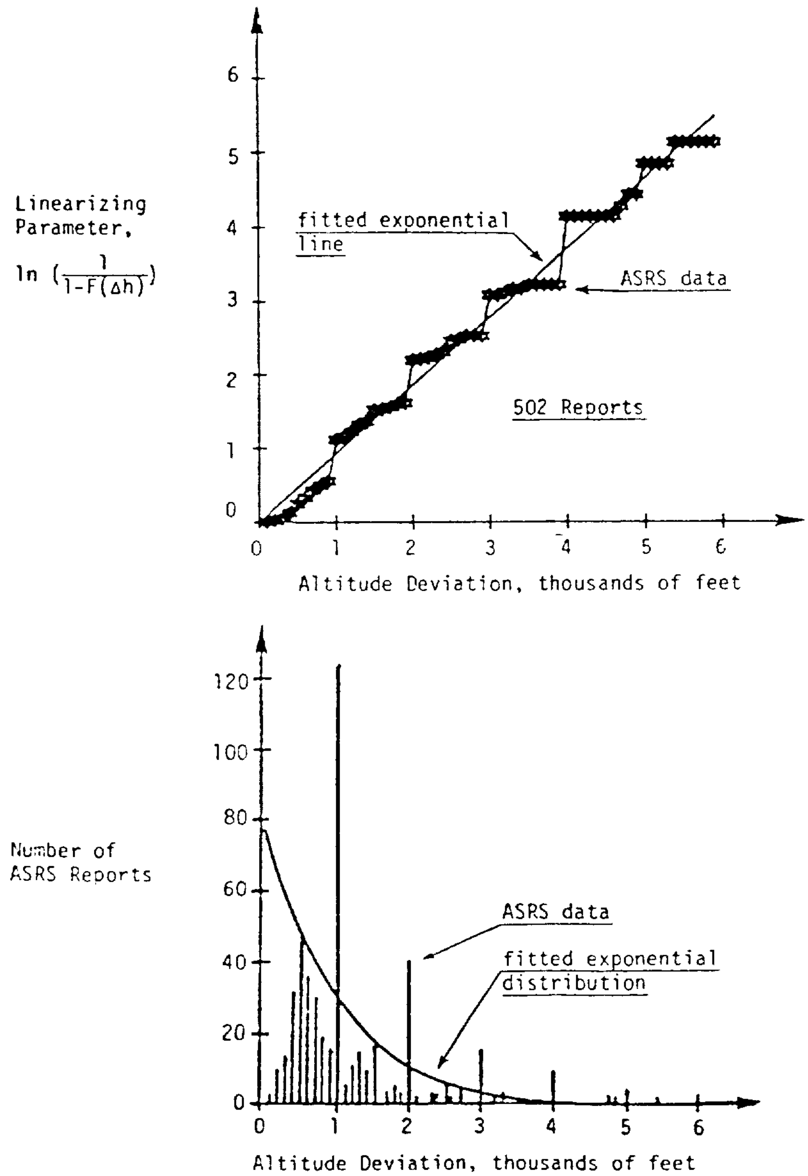


FIGURE 4. DISTRIBUTION OF MAGNITUDES OF REPORTED ALTITUDE DEVIATIONS

- Failures-to-level versus failures-to-maintain versus failures-to-attain versus unclassifiable flight patterns.
- Pilot versus controller versus pilot and controller reports.
- Military aircraft involvement versus no military aircraft involvement.
- Conflict, evasive action taken or no time versus conflict, no known evasive action taken versus no conflict requiring evasive action.

Exponential distributions fitted to subgroups. - Figure 5 shows plots of linearized cumulative exponential distributions fitted to 12 of the subgroups associated with the various partitionings. If the altitude deviations for each subgroup had a perfect exponential distribution, the data for each subgroup would lie along a straight line passing through the origin. Except for the perturbations due to the concentrations of the data at 1000 ft intervals, it is seen that the fitted straight lines well represent the data in each of the subgroups. These plots show that exponential distributions provide excellent descriptions of the altitude deviations for each subgroup.

As shown in Appendix C, one estimate of the mean altitude deviation for each subgroup is given by the reciprocal of the slope of the fitted regression line that is constrained to pass through the origin. The numerical values of these estimated means are shown in Table 3, and discussed later in this section.

Because of the markedly different types of groups represented by these plots, it is concluded that the exponential distribution provides a "robust" representation of altitude deviations. Many meaningful subgroups of the original data, including partitionings not reported here, such as low versus high altitude, and integer multiples of 1000 ft versus noninteger multiples of 1000 ft, were found to be well represented by exponential distributions.

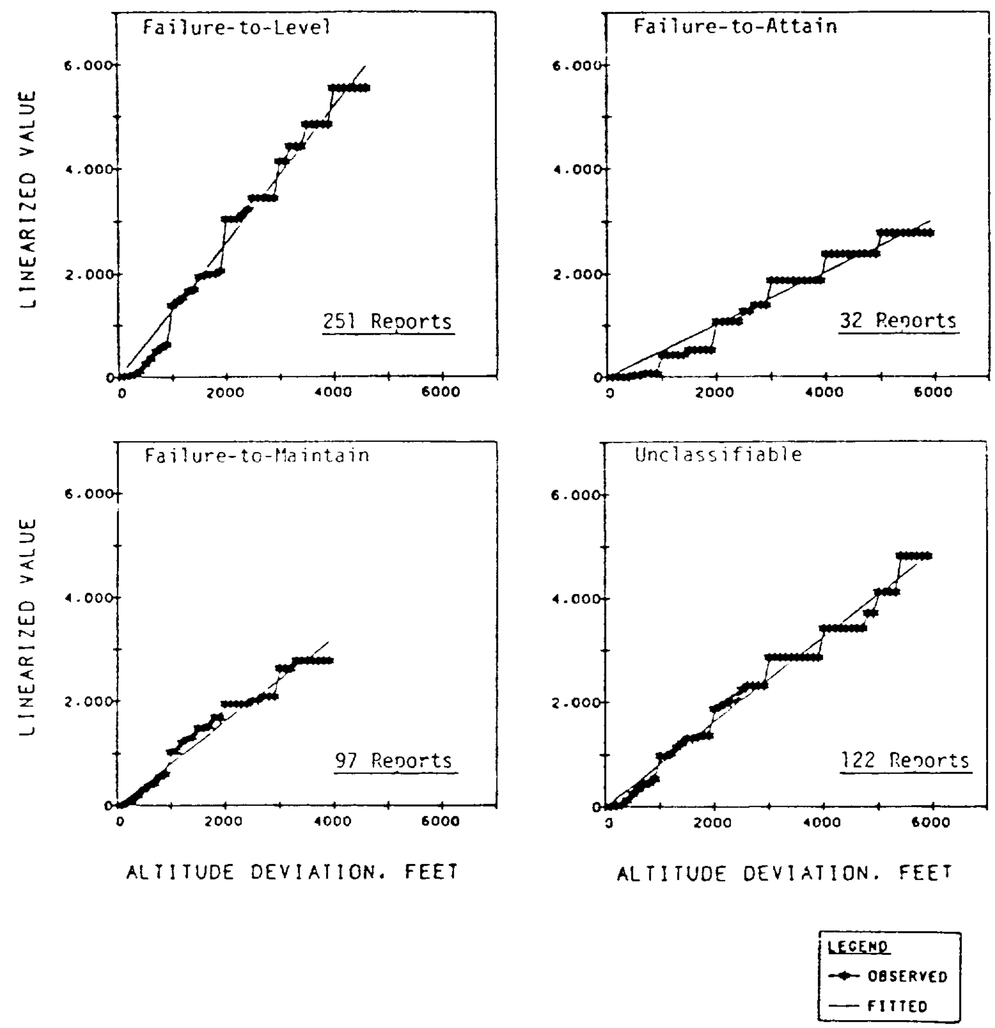


Figure 5a. Deviations Partitioned
By Flight Pattern

FIGURE 5. APPROXIMATE TRANSFORMED EXPONENTIAL DISTRIBUTIONS OF ALTITUDE DEVIATIONS OF SUBGROUPS

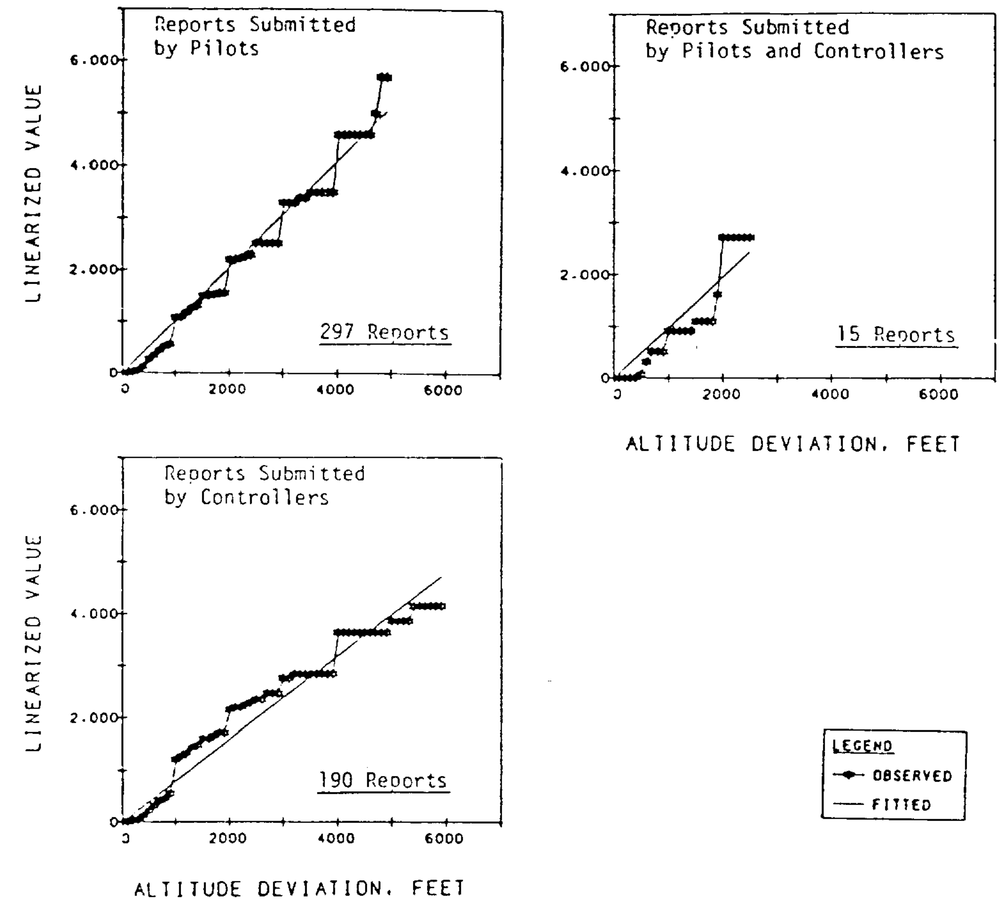


Figure 5b. Deviations Partitioned by Reporter

FIGURE 5. APPROXIMATE TRANSFORMED EXPONENTIAL DISTRIBUTIONS OF ALTITUDE DEVIATIONS OF SUBGROUPS (CONTINUED)

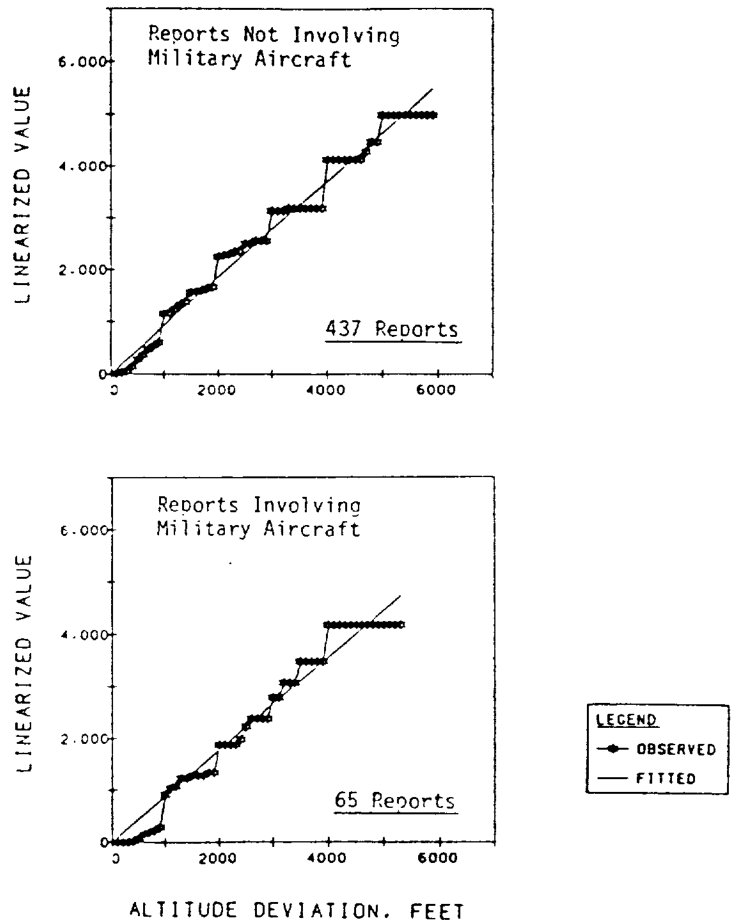


Figure 5c. Deviations Partitioned By Military Aircraft Involvement

FIGURE 5. APPROXIMATE TRANSFORMED EXPONENTIAL DISTRIBUTIONS OF ALTITUDE DEVIATIONS OF SUBGROUPS (CONTINUED)

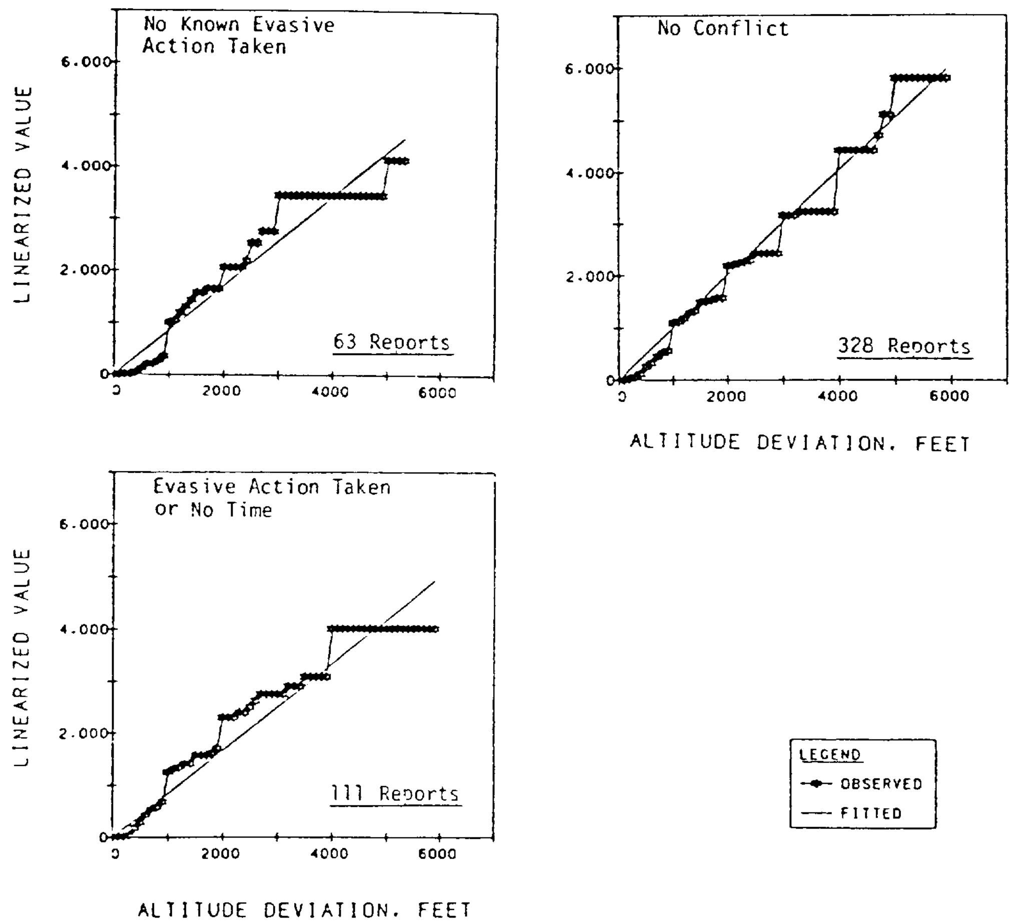


Figure 5d. Deviations Partitioned
By Conflict and
Evasive Response

FIGURE 5. APPROXIMATE TRANSFORMED EXPONENTIAL DISTRIBUTIONS OF ALTITUDE DEVIATIONS OF SUBGROUPS (CONTINUED)

Means of subgroup distributions. - Table 3 shows the mean values of the fitted exponential distributions for the various subgroups, with the corresponding 95 percent confidence intervals for these means. These values are rounded to the nearest 10 ft. The table shows, for example, that 251 reports involve failures-to-level. The mean altitude deviation for this group is approximately 770 ft. With a confidence of 95 percent, the true mean for failures-to-level lies between 680 and 870 ft. The mean values for flight pattern subgroups range between 770 ft (failures-to-level), to 1960 ft (failures-to-attain). Appendix B discusses these findings for flight pattern subgroups in detail.

Figure 6 shows graphical representations of the mean altitude deviations and associated 95 percent confidence intervals for the subgroups identified in Table 3. A rough graphical test for the statistical equivalence among the means is obtained by noting whether or not the confidence limits share common values. For example, a horizontal line can intersect the vertical bars for the failures-to-maintain and the failures-to-attain. Based on this test, it is concluded that the mean altitude deviations for these two subgroups do not differ statistically. In contrast, no horizontal line can intersect the vertical bars associated with the failure-to-level and failure-to-maintain subgroups. Consequently, these means are judged to differ by a statistically significant amount. This examination shows that the mean of the failure-to-level subgroup is statistically smaller than the means of both the failure-to-maintain and failure-to-attain subgroups.

Although Table 3 and Figure 6 show that the 95 percent confidence intervals for the pilot and controller reports overlap by a small amount, the more exact statistical tests given in Appendix C show that these mean altitude deviations differ statistically at the 5 percent level of significance. Thus, the data indicate that the mean altitude deviation reported by pilots is statistically smaller than that reported by controllers; the difference is not attributed to chance.

Both the graphical and numerical tests indicate that no statistical significance can be assigned to the difference between the mean altitude

TABLE 3. MEAN ALTITUDE DEVIATIONS OF SUBGROUPS

| Subgroup | Number of Reports | Altitude Deviation, feet | |
|---|---|---|---|
| | | Mean[a] | 95 Percent Confidence Interval[b] |
| Partitioned by Flight Pattern | | | |
| Failure-to-Level | 251 | 770 | ( 680, 870) |
| Failure-to-Maintain | 97 | 1240 | (1000, 1500) |
| Failure-to-Attain | 32 | 1960 | (1340, 2690) |
| Unclassifiable | 122 | 1230 | (1020, 1450) |
| Partitioned by Reporter | | | |
| Pilot | 297 | 970 | ( 870, 1090) |
| Controller | 190 | 1250 | (1080, 1440) |
| Pilot and Controller | 15 | 1030 | ( 560, 1590) |
| Partitioned by Military Aircraft Involvement | | | |
| No Involvement | 437 | 1080 | ( 980, 1190) |
| Involvement | 65 | 1120 | ( 860, 1460) |
| Partitioned by Conflict/Evasive Response | | | |
| Evasive Action or No Time | 111 | 1200 | ( 980, 1420) |
| No Known Action Taken | 63 | 1160 | ( 880, 1470) |
| No Conflict | 328 | 990 | ( 880, 1100) |
| Combined Data Set | | | |
| | 502 | 1080 | ( 980, 1180) |

(a) Mean values are estimated using the reciprocals of the slopes of the regression lines fitted to the linearized cumulative exponential distribution and constrained to pass through the origin (See Appendix C).

(b) These confidence intervals are based on a large sample approximation to the Chi Square distribution (See Appendix C).

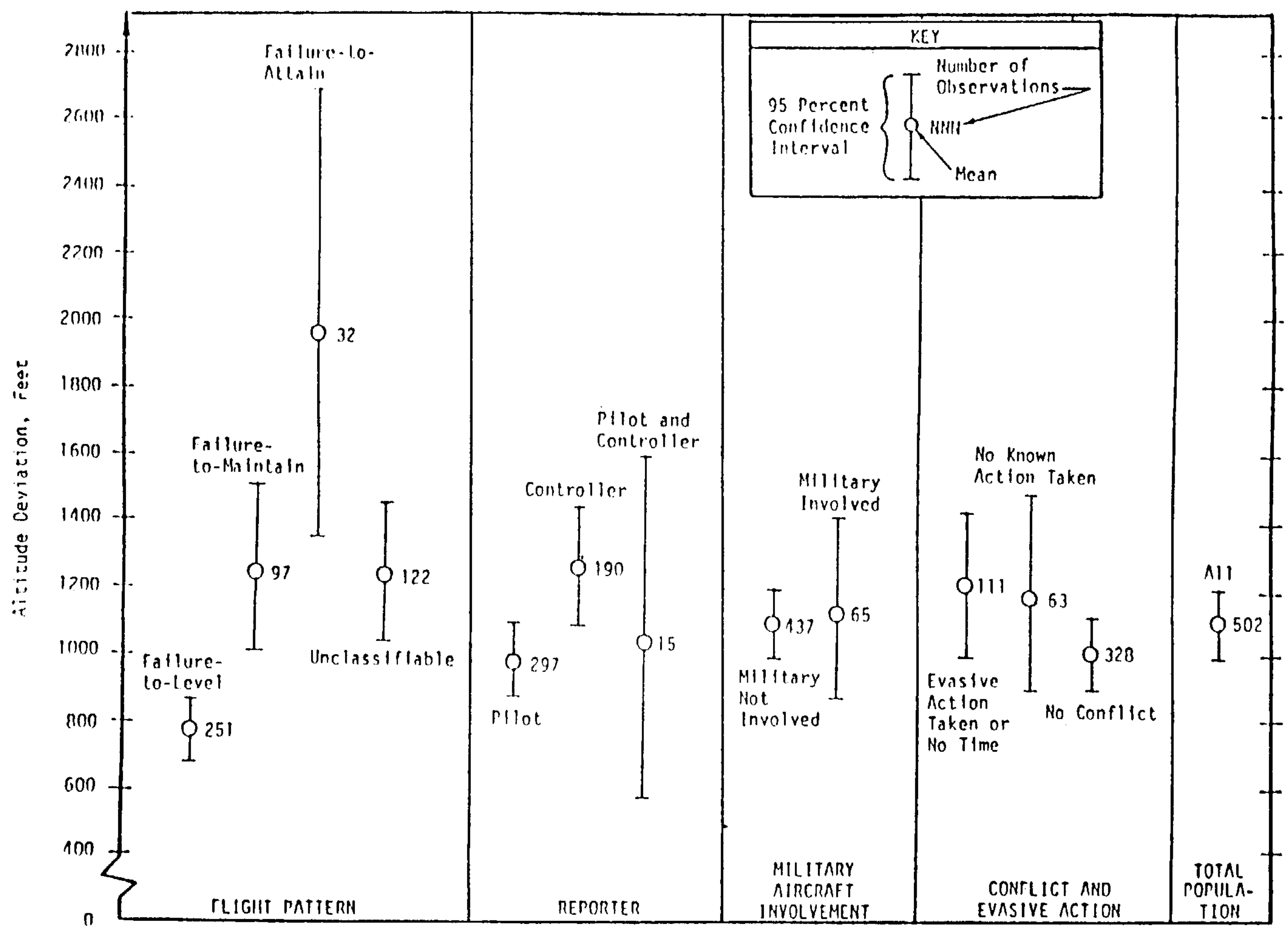


FIGURE 6. MEANS OF EXPONENTIAL DISTRIBUTION OF SUBGROUPS

deviations associated with the involvement, or noninvolvement, of military aircraft in the deviation incident. The calculations given in Appendix C indicate that the mean altitude deviations for reports involving evasive actions show borderline difference from those where no conflicts among aircraft were reported.

### Concentrations of Computed Deviations At Multiples of 1,000 Feet

Altitude assignments are usually given in multiples of 1000 or 2000 ft. These are termed cardinal altitudes. By contrast, the flight altitudes of aircraft can be reported in units of 100 ft, and they often are in ASRS narratives. Altitude deviations are computed as the difference between a flight altitude and an assigned altitude, resulting in a measure expressed in units of 100 ft.

As noted earlier, the data show marked concentrations at values that are multiples of 1000 ft (cardinal values). This is illustrated in the histogram in Figure 4. It is an unanticipated finding. To determine the reasons for these concentrations at cardinal altitudes, incident reports with cardinal valued deviations were reviewed with four alternative explanations in mind: (1) the reporter rounded the actual flight altitude to the nearest cardinal altitude causing a cardinal valued deviation to be computed, (2) the aircraft was flying level at an unassigned cardinal altitude, (3) the aircraft came in conflict with another aircraft at a cardinal altitude (reported as the deviating aircraft's flight altitude), or (4) the aircraft reported leaving from or arriving at an unassigned cardinal altitude to a controller who then recognized the deviation.

The review of incidents with cardinal valued deviations reveals the following. Two hundred of 502 incidents have cardinal valued deviations. Assuming that the underlying distribution is exponential, only 30 cardinal observations would be expected. Twenty-six of the incidents have language suggesting the reporter rounded the flight altitude to a cardinal value. Eighty-eight incidents involve aircraft flying level at unassigned altitudes. In 25 incidents, cases the deviating aircraft came into conflict with another aircraft at the second aircraft's assigned cardinal altitude. In two cases, the pilot reported leaving from, or arriving at, an unassigned altitude. Fifty-nine cases were unexplained.

Thus, the majority of the cardinal valued deviations reported result from aircraft flying level at unassigned cardinal altitudes or coming into conflict with other aircraft at unassigned cardinal altitudes. Less than 20 percent of the observations are clearly attributable to the rounding of flight altitudes to the nearest 1000-ft cardinal altitude by the report.

### Some Noncorrelations

A number of scatterplots were generated in order to determine whether certain variables are correlated with the magnitudes of altitude deviations. For example, for each aircraft the magnitude of the altitude deviation was plotted against the assigned altitude. This was done to determine whether large altitude deviations tend to occur at high altitudes, with small deviations occurring at low altitudes. No correlation is found; the R-squared value is 0.005. [A perfect correlation would be represented by an R-squared value of 1.0 on a scale of 0 to 1.]

A scatterplot was also generated for the evasive action reports. Here, the reported horizontal and vertical miss distances were first converted to a single line-of-sight miss distance. This distance was then plotted against the magnitude of the altitude deviation to determine whether, for example, small miss distances might tend to occur when altitude deviations were large. Again, no correlation is found. The R-squared value is 0.007.

## DISCUSSION

Figures 2 and 4 show that the magnitudes of reported altitude deviations are well represented by exponential distributions, even over different subgroups defined by flight pattern, by reporter, and by conflict incidents involving different kinds of evasive action. It was not anticipated that any single distribution would provide such an excellent fit to the data. The mix of flight patterns, the lower-bound interpretation of the computed altitude deviation, the possible nonreporting of small deviations, and the uncertain effects of rounding all contribute to the expectation that considerable "scatter" and "noise" would obscure the data interpretation. Because this did not happen, several questions arise. Why are reported altitude deviations exponentially distributed? Are there properties of such altitude deviations that would necessarily yield exponential distributions? Are there unifying reasons why the various subgroups yield distributions of identical form?

In the discussion that follows, arguments are given to support an interpretation of altitude deviations in terms of time. To do this, note that, at a constant rate of climb or descent, the magnitude of an altitude deviation is directly proportional to the time that it remains undetected after its inception point. Less precisely, on the average, large altitude deviations exist a long time before detection. This idea is developed in more detail in the following paragraphs. The resulting arguments are intended to explain the exponential form of the distribution of altitude deviations, and to suggest that similar results may also hold for certain other types of aviation safety related occurrences.

To the extent that the observed distributions represent times-to-detect, they are best understood as the times for <u>humans</u> to detect deviations. The standard mechanical controls on altitude deviations, autopilots and altitude alert mechanisms, will generally restrain deviations to 300 ft or less. The preponderance of observations in the database exceed that figure. They represent a class of control anomalies where mechanical control devices failed, were overridden, or otherwise proved ineffective. It was the human controllers -- pilots, crews, and air traffic controllers -- who detected the problem.

## The Exponential Distribution

The exponential distribution has many applications in physics and reliability engineering. In engineering, it is frequently used to describe various time intervals such as time-to-failure or mean-time-between-failures. In short, exponential distributions frequently arise in problems where time intervals are random variables. The exponential distribution is one of the few continuous distributions that has only one parameter. This parameter can be interpreted as the mean, or as the standard deviation, of the distribution. Because the distribution has only one parameter, it is not particularly flexible in fitting data. For this reason, together with those cited earlier, the exponential distribution was not expected to fit the distribution of altitude deviations.

## At Constant Rates of Climb and Descent, The Times to Detect Altitude Deviations Are Exponentially Distributed

In Appendix C it is shown that if the altitude deviation, $\Delta h$, is exponentially distributed, and if $\Delta h$ is divided by a constant reference rate of climb or descent, $\dot{h}$, then the result, $\Delta h/\dot{h}$, will also be exponentially distributed. The ratio $\Delta h/\dot{h}$ has units of time, and is directly interpretable as the time required to climb or descend a vertical distance, $\Delta h$, starting at time 0, with a constant rate of climb or descent equal to $\dot{h}$. If the altitude deviation is undetected at time 0, then $t = \Delta h/\dot{h}$ also represents the incremental time taken to detect the existence of the altitude deviation.

Note that the computed altitude deviations generally represent lower bounds to the maximum altitude excursions. Approximately 65 percent of the reports yield lower-bound estimates. For a study of the times to detect altitude deviations, a lower-bound estimate resulting from the use of the detection point as the flight altitude reference provides nearly the data desired. It represents the time required to detect the deviation after its emergence. The altitude deviation associated with the maximum excursion, when divided by $\dot{h}$, yields an estimate of the detection time plus the additional time required to halt the excursion after detection. The preferred measure for detection time is the altitude deviation measured as the difference between the detection altitude and the inception altitude. However, this difference could not be inferred from most ASRS narratives.

## Some Numerical Interpretations

The mean altitude deviation for the 502 reports is approximately 1080 ft. Based on a reference rate of climb or descent of 1500 ft/min, typical for altitudes approximating 10,000 ft, it follows that the corresponding mean time to detection is approximately 43 seconds. At altitudes around 15,000 ft, with a reference rate of 600 ft/min for ascent and 3000 ft/min for descent, the resulting mean times to detection are computed to be 108 seconds and 22 seconds, respectively.

The reference climb and descent rates used in this analysis are believed to be broadly representative of the range of values encountered in the aviation environment. However, the correspondence between the arbitrarily chosen reference values and empirical average rates is unknown. Thus, the calculated average times-to-detect should be regarded as illustrative, with different reference values giving rise to different detection times, as indicated by the examples.

Symmetrical distributions have cumulative probabilities that are 50 percent below and 50 percent above the mean value of the distribution. In contrast, the exponential distribution is unsymmetric and has approximately 63 percent of its probability below and 37 percent above the mean value. For this reason, the mean value of the exponential distribution is sometimes replaced by a measure called the "half-life". The half-life represents that value for which the probabilities are divided with 50 percent below and 50 percent above the half-life value. The half-life for the exponential distribution is given by $\tau \ln 2$, or $0.69\ \tau$, where $\tau$ is the mean of the distribution. Thus, the half-life for the exponential distribution is approximately 70 percent of the mean value.

A mean altitude deviation of 1080 ft and a reference rate of change of altitude of 1500 ft/min yields $43 \ln 2$ or approximately 30 seconds for the half-life. That is, for the set of 502 reports, 50 percent of the deviation would be detected before the elapse of 30 seconds and 50 percent would be detected after the elapse of 30 seconds, provided the reference rate for change of altitude is assumed to be 1500 ft/min.

If it is further assumed that the distribution of 502 altitude deviations is representative of all altitude deviations, an actual altitude deviation that occurs in the future can be treated as a random drawing from this population of 502 deviations. On this basis, an altitude deviation that occurs in the future, at a reference rate of 1500 ft/min, can be predicted to have a half-life of 30 seconds; that is, there is a 50 percent probability that the altitude deviation will be detected within 30 seconds. If the reference rates are taken to be 3000 ft/min and 600 ft/min, then the corresponding half-lives are found to be 15 seconds and 75 seconds, respectively.

## Mathematical Assumptions That Yield Exponentially Distributed Detection Times

Suppose, for example, an altitude deviation is undetected at time 0, and the probability it is still undetected at a subsequent time $t/\tau$ is expressed as $Q = 1-(t/\tau)$, with t denoting the mean time to detection. Under these familiar and frequently occurring assumptions, the exponential distribution necessarily follows. The result holds even if the expression $Q = 1-(t/\tau)$ is true only in an approximate sense (to within higher powers of $t/\tau$). This argument supports exponential distributions of detection times and is compelling partly because of the simplicity of the underlying assumptions. A more detailed mathematical derivation is given in Appendix C.

## Possible Generalizations to Other Aviation Safety Problems

It is possible to regard some of the operational activities of both pilots and controllers as involving sequences of timely detection and correction of problems. Some of these problems come into existence but remain undetected until some later time. If the problem remains undetected for a small time $t/\tau$, and if the probability of nondetection can be expressed as $Q = 1-(t/\tau)$, then the detection times will be exponentially distributed. This is a reasonable assumption for those problems that come into existence and persist until detection as a result of random surveillance. Such problems would likely include heading errors, communication errors, chart-reading errors, crew misunderstandings, etc.

## Some Statistical Caveats

It should be noted that the graphical procedure used in Figure 3 is an unsophisticated test of statistical significance. Although the statistical tests in Appendix C are more refined, there is considerable uncertainty regarding the best way to estimate the mean values of the approximating exponential distributions.

The computed arithmetic mean obtained directly from the data does not provide a suitable estimate of the mean of the best approximating exponential distribution. Better estimates are obtained by linearizing the cumulative plots and then fitting regression lines that are constrained to pass through the origin. The mean is then given by the reciprocal of the slope of the fitted line.

In the present application, analytical methods for fitting exponential distributions presuppose that relatively large amounts of data would lie in the interval between 0 and 100 ft. However, deviations of this amount are not reported. Thus, the actual data is severely truncated at less than 100 ft, and may well be partially truncated over a range of several hundred feet.

The problem of truncation must be considered along with the fact that the data are concentrated at integer multiples of 1000 ft with some rounding. These problems complicate the estimation of the mean altitude deviation for any subgroup. Although the slopes and corresponding mean values are uncertain, the straight lines fitted to the data leave little doubt that exponential distributions describe the altitude deviations for each subgroup.

# CONCLUSIONS

The conclusions resulting from this study are:

- Deviations from ATC assigned altitudes are equally likely to be above or below the assigned altitude.
- No correlation exists between the magnitude of an altitude deviation and the assigned altitude. (Large deviations are not associated with high altitudes.)
- Except for 6 reported deviations in excess of 6000 ft, altitude deviations are found to be approximately exponentially distributed with a mean of 1080 ft.
- The altitude deviations show concentrations at integer multiples of 1000 ft. Less than 20 percent of this concentration is attributed to rounding. About 80 percent is attributed to deviating aircraft flying level at unassigned altitudes or coming into conflict with other aircraft at altitudes to which the deviating aircraft are not assigned.
- Evasive actions are involved in 111 reports. The evasive actions generally occur as a result of altitude deviations; not conversely.
- For evasive action reports with miss distances, no correlation is found between the magnitude of the miss distance and the magnitude of the altitude deviations.
- Altitude deviations are exponentially distributed for various subgroups of the data. The subgroups include pilot reports, controller reports, incidents involving military aircraft, incidents involving evasive actions, and incidents where the pilot failed to level, failed to maintain, or failed to attain the assigned altitude.

The authors conclude that the exponential form of the distribution of altitude deviations can be supported, and possibly inferred directly, by interpreting the results for altitude deviations in a time domain. With this interpretation, the exponential distribution represents the distribution of times to detect altitude deviations, under the assumption that the rate of climb or descent is approximately constant. With 50 percent probability, the times to detect an altitude deviation are computed to vary between 15 and 75 seconds for reference rates of descent or climb of 3000 and 600 ft/min, respectively. At a reference rate of 1500 ft/min, the mean time to detect an altitude deviation is 43 seconds. This means that the probability is approximately 63 percent that a given altitude deviation will be detected within 43 seconds; the half-life of an altitude deviation at this rate is computed to be 30 seconds.

It is believed that these detection times should be interpreted as times for human detection. Altitude alerts, autopilots, and other altitude warning and controlling devices are generally inoperative, overridden, or otherwise failed in their control function for most of the altitude deviations in the database.

The conclusions involving detection times are not based on reported or measured detection times. Instead, the conclusions are derived from a reinterpretation of the observed exponential distributions based on information contained in ASRS reports. The finding that altitude deviations are exponentially distributed is not readily explainable in the spatial domain. By contrast, a detection time interpretation yields simple, well-known explanations. Moreover, several related areas of inquiry are suggested. Are the magnitudes of the detection times excessive? If so, does this reflect over reliance on mechanical control devices? What can be done to reduce the detection times? Is the detection time for an altitude deviation comparable to the half-life of a "typical distraction"?

The general argument for exponentially distributed detection times may be applicable to a variety of other aviation safety problems. Candidate problems include those that come into existence and persist until subsequent detection. On this basis, exponential distributions, each with its own half-life, may describe the distribution of times to detect heading errors, communication errors, etc.

This study shows that detection times are well-characterized by exponential distributions in widely differing contexts involving altitude deviations. The inherent stability of this result suggests that the concept of detection time may provide a useful way of characterizing certain problems of aviation safety, and that focusing on the reduction of detection times may improve aviation safety.

Despite the nonrandomness of the ASRS database and a host of other statistical problems, this study also demonstrates the possibility of using ASRS data to obtain improved quantitative understanding of problems related to aviation safety.

# APPENDIX A

## AN EXAMINATION OF THE CONCENTRATION OF ALTITUDE DEVIATIONS AT INTEGER MULTIPLES OF 1000 FEET

# APPENDIX A

## AN EXAMINATION OF THE CONCENTRATION OF ALTITUDE DEVIATIONS AT INTEGER MULTIPLES OF 1000 FEET

### INTRODUCTION

The distribution of the 502 computed altitude deviations, grouped at 100-ft intervals, is shown in the upper half of Figure A-1. It shows large concentrations of deviations at integer multiples of 1000 feet. This does not appear to be a random phenomenon. Rather, it suggests the existence of an internal structure within the 1000-ft histogram bars shown in the lower half of Figure A-1.[a]

To understand the significance of the cardinal concentrations, it is useful to recall the manner in which the magnitudes of altitude deviations were computed. ASRS reports are free-form narratives. Reporters are not explicitly asked to provide quantitative information describing the magnitude of an altitude deviation. Rather, they are asked to volunteer whatever information they feel is important regarding whatever type of incident they are reporting. For altitude deviations, reporters usually provide the assigned altitude of the deviating aircraft and its flight altitude at some point during the excursion -- frequently not the maximum excursion point. Using these data it is possible to calculate a lower bound measure of the magnitude of the altitude deviation. It is shown that the type of flight altitude data provided by the narratives tends to promote the calculation of cardinal altitude deviations.

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[a]To simplify exposition, the term "deviation" is used to denote the absolute value of the magnitude of an altitude deviation measured in feet, and the adjective "cardinal" denotes a measure stated as an integer multiple of 1000 feet, as in cardinal value or cardinal observation.

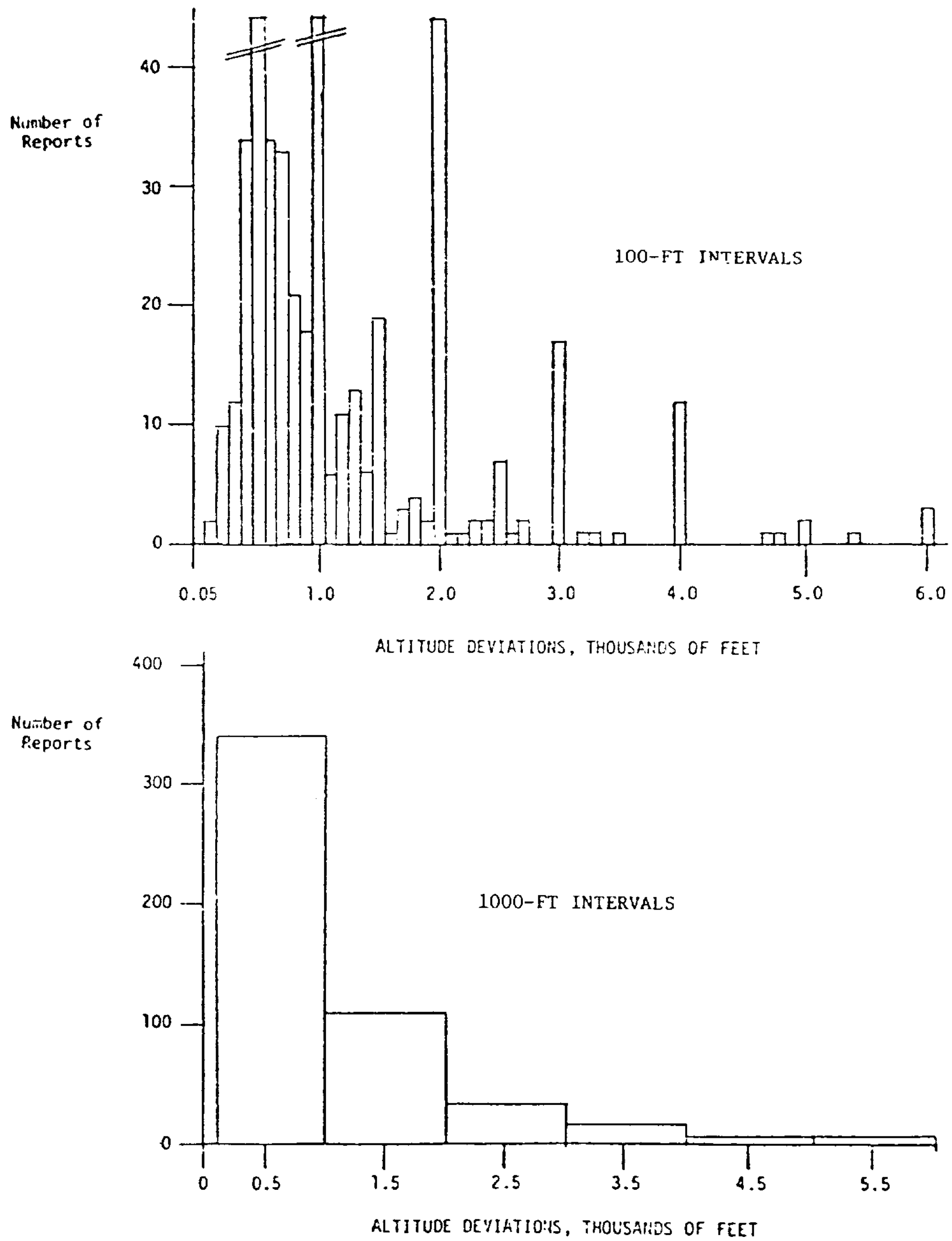


FIGURE A-1. ALTERNATIVE HISTOGRAMS OF REPORTED ALTITUDE DEVIATIONS

## Magnitude of the Concentrations

Before discussing the causes of the cardinal concentrations, it is desirable to quantify, in some reasonably precise fashion, the magnitude of the disparity between (1) the observed number of cardinal observations, and (2) the statistically expected number of such observations.

Statistically expected observations. - The calculation of the statistically expected number of cardinal observations is based on the premise that the observed distribution is exponential. As the main text indicates, there is a sound basis for this premise and none of the statistical tests performed on the data serve to reject it.

The population of 502 cases can be approximated by a geometric distribution of the following form:[a]

$$(0.1)(0.9)^{d-1},\ d = 1,\ 2,\ldots$$

where d = 1 for 100 feet, d = 2 for 200 feet, etc.

As shown in the two parts of Figure A-1, the observed distribution is comprised of 60 100-ft intervals that can be aggregated into 6 1000-ft intervals; these 6 can then be superimposed. The resulting distribution groups deviations with the values 100, 1100, 2100, 3100, 4100, and 5100, for example, in one group; 200, 2200 ..., 5200 in another; and so on. The first group includes all reports with 1000, 2000, ..., 6000-ft deviations. It is easily calculated that approximately 5.9 percent of all reports would be expected to fall in the first (cardinal) group if the underlying distribution is geometric using 100-ft intervals. The expected values for the other intervals can be calculated as well. If the distribution is not geometric at this level of disaggregation, significant differences will exist between the expected and observed number of reports in two or more of the superimposed 100-ft groups.

[a] This formula is an approximate geometric representation, at 100-ft intervals, of an exponential distribution having a mean altitude deviation of 1000 feet which is the approximate mean of the overall distribution. See Appendix C for exact representation.

Observed versus expected numbers of reports. - The expected number of reports in each of the superimposed 100-ft intervals is shown in Table A-1. Also presented are the observed number of reports in these intervals and the difference between expected and observed values.

TABLE A-1. OBSERVED VERSUS EXPECTED NUMBERS OR REPORTS IN SUPERIMPOSED 100-FT INTERVALS

| 100-Ft Interval | Expected Percentage of Reports | Expected Number of Reports[a] | Actual Number of Reports | Difference Between Observed and Expected Numbers |
|---|---|---|---|---|
| 000 | 5.9 | 30 | 200 | +170 |
| 100 | 15.4 | 77 | 9 | -67 |
| 200 | 13.8 | 69 | 23 | -46 |
| 300 | 12.4 | 62 | 29 | -33 |
| 400 | 11.2 | 56 | 43 | -13 |
| 500 | 10.1 | 51 | 77 | +26 |
| 600 | 9.1 | 46 | 36 | -10 |
| 700 | 8.2 | 41 | 39 | -2 |
| 800 | 7.4 | 37 | 26 | -11 |
| 900 | 6.6 | 33 | 20 | -13 |
| Total | 100.1 | 502 | 502 | 1[b] |

[a]The expected number is based on a population of 502 observations and an assumed underlying geometric distribution of the form $(0.1)\ (0.9)^{d-1}$.

[b]Cumulative rounding error; corrected value would be zero.

Table A-1 indicates that there are approximately 6 times more observations than expected at cardinal values and 51 percent more observations than expected at the 500-ft values. The overall pattern in the data is depicted in Figure A-2 showing the percent differentials for each class interval of 100 feet. The interval distribution of observations within the 1000-ft histogram bars is a W-shaped structure that does not appear to be randomly generated.

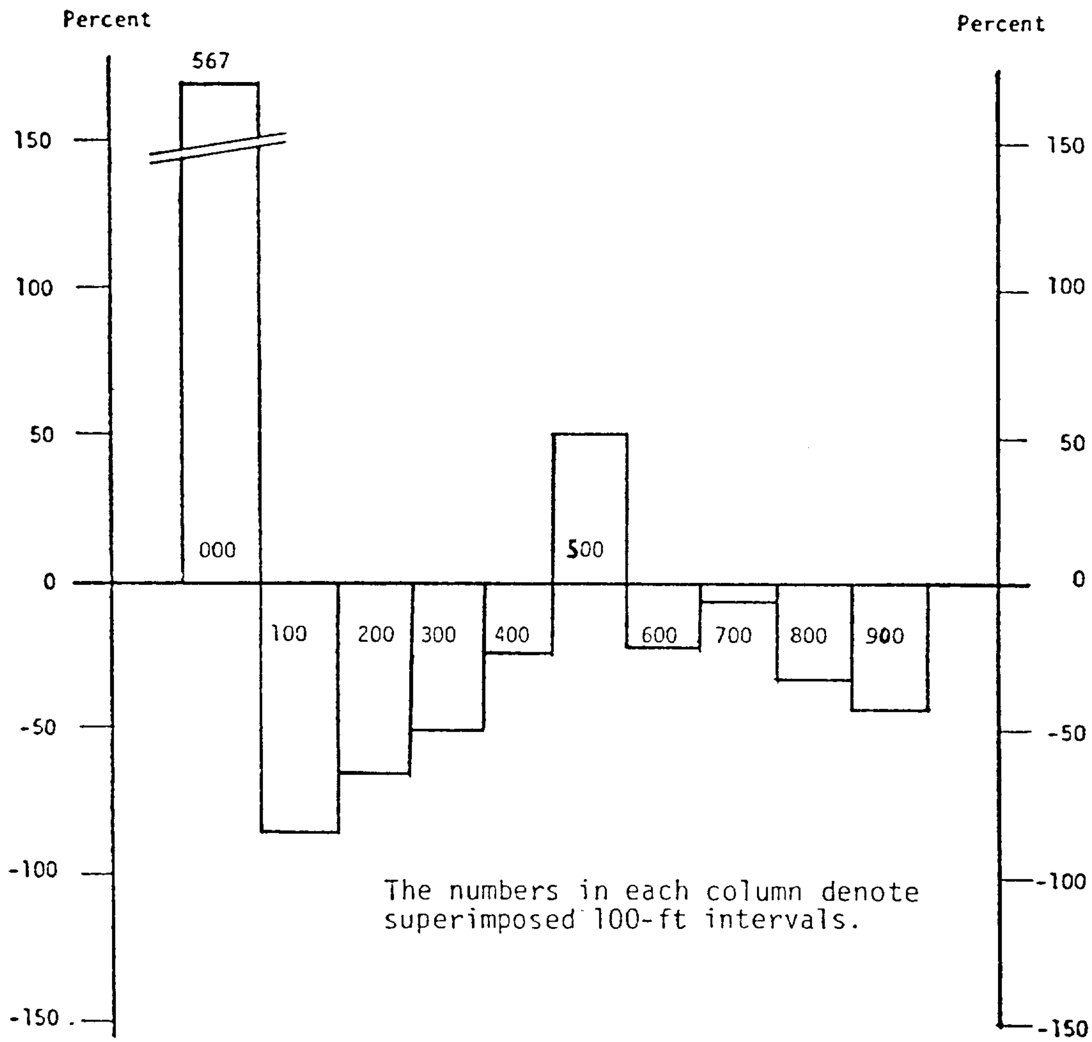


FIGURE A-2. PERCENT DIFFERENCE BETWEEN OBSERVED AND EXPECTED NUMBERS OF REPORTS OF ALTITUDE DEVIATIONS AT SUPERIMPOSED 100-FT INTERVALS

The W-shaped structure suggests that reporters may be rounding flight altitudes to either a value of 500 or 1000. But, there are a number of possible explanations other than rounding for the reported concentrations. These are discussed next.

## Candidate Explanations

Rounded. - As noted earlier, the concentrations of computed altitude deviations at cardinal values may manifest "rounding" on the part of the reporter. In this context, the term denotes (1) recollecting the magnitude of the deviation at only the 500 or 1000-ft level of precision, or (2) a decision to report the deviation at a level of precision no greater than 500 or 1000 feet even though a more precise value was known, or (3) an inability to report the magnitude of the deviation with greater precision perhaps because of the manner in which instruments were scanned during the deviation.

This particular usage of the term "rounding" is broader than generally used and does not imply an indifference to precision on the part of reporters.

Substantive. - It may be that the observed cardinal concentrations do not result from rounding; rather, they may manifest some substantive mechanism that either places a disproportionate number of deviating aircraft at cardinal altitudes or causes them to be detected there.

For example, the aircrew of a nondeviating aircraft may detect an excursion as a deviating aircraft passes through its altitude. The natural reference point for the flight altitude of the deviating aircraft is the assigned altitude of the nondeviating aircraft.

Many pilots follow this communications protocol: they radio arrival at, departure from, or approach to, their assigned altitude. If the pilot had a mistaken understanding of his clearance, his mistake might be detected by the controller when the pilot reports leaving or approaching the cardinal altitude. Still another possibility is that the deviating aircraft was actually maintaining level flight at an unassigned altitude perhaps because of confusion regarding the altitude clearance. Such deviations would typically be detected at a cardinal altitude.

The term "substantive" is used to describe this group of explanations because they are not mere artifacts of the reporting system. They are substantive events generally involving deviating aircraft that flew level at unassigned cardinal altitudes. Such deviations increase the likelihood of midair collisions, and are therefore particularly serious occurrences.

## RESEARCH APPROACH

Each of the 200 reports with cardinal deviations was re-examined in an attempt to establish the reasons for the large cardinal concentrations and for the W-shaped structure within the 1000-ft histogram bars. The analysis was performed with particular reference to the candidate explanations cited above. For most reports, an explanation for the deviation's cardinality was established. These findings are presented next.

## FINDINGS

Findings from the review of cardinal deviation reports are shown in Table A-2. Observations are classified in Table A-2 in terms of the candidate explanations. It can be seen that each of the candidate explanations has some merit. But, the single most important reason for the large number of cardinal observations was the maintenance of level flight by a deviating aircraft at a cardinal flight altitude. (In a few instances the deviation was detected just as the aircraft leveled off.)

Of the 200 cardinal deviations, 38 are unexplained in the sense that neither the narratives nor statistical inference could be used to account for

TABLE A-2. REASONS FOR CARDINAL ALTITUDE DEVIATIONS

| Reason | Reports |
|---|---|
| Rounded | |
| - Used language which suggested rounding[a] | 26 |
| Substantive | |
| - Reported flight altitude of deviating aircraft as assigned altitude of a second conflicting aircraft | 25 |
| - Flying level or leveling at an unassigned altitude | 88 |
| - Pilot reported leaving from or arriving at an unassigned cardinal altitude to controller | 2 |
| Unexplained[b] | 59 |
| Total | 200 |
| Expected | (29.6) |

[a]Terms used by the reporter, such as "about", "approximately", "near", were interpreted as rounding terminology.

[b]Some of the reports in this category might have been classified as "rounded" or "substantive" if the narratives had been more complete.

their cardinality.[a] This does not mean that these reports, which comprise 19 percent of all cardinal observations, are necessarily different from the rest. This may be so, but an alternative explanation is they could have been placed in one of the other two categories (rounded, substantive) if the narratives had been more complete.

[a]There are 59 observations which are unexplained by the narrative. Of these, 21 were statistically expected to be cardinal. Thus, 38 are completely unaccounted for.

## DISCUSSION

Rounding is a significant cause of the concentration of deviations at cardinal values (although it is not the most prominent reason). Twenty-six of the cardinal values are clearly attributable to rounding. It is also possible that the W-shaped internal distribution of the 1000-ft histogram columns and the limited concentration of reports at the 500-ft marks are at least partially attributable to rounding. If this is true, deviations were rounded to both the 500-ft and 1000-ft marks creating deficits in the remaining 100-ft categories, thus explaining the W-shaped internal distribution within the 1000-ft histogram bars.

It is important that in 88 out of 200 reports, the deviating aircraft was flying level at an unassigned cardinal altitude. In some, the aircraft failed to depart from a previously assigned altitude for a new one. In others, the aircraft leveled prematurely, or leveled at an altitude beyond the one to which it had been assigned. This phenomenon is related to misset or misread altimeters, misunderstood altitude clearance, and to aircrews mistaking other aircrafts′ clearances for their own.

In another 25 reports, the deviating aircraft came into conflict with a second nondeviating aircraft, and the size of the deviation was measured as the difference between the assigned altitudes of the two aircraft.

Obviously, the substantive cardinal observations -- aircraft conflict reports and those involving level, deviating aircraft at cardinal altitudes -- represent particularly hazardous altitude deviation incidents. They constitute a significant portion, 23 percent, of the total population of 502 reports.

## CONCLUSIONS

Approximately 58 percent of the reported cardinal deviations are directly attributed to aircraft flying level, or leveling at an unassigned altitude, or flying through an altitude assigned to another aircraft.

Approximately 13 percent of the reported cardinal deviations are directly attributed to rounding. The remaining 29 percent are associated with reports that cannot be classified because of insufficient information. If these reports are allocated in proportion to the reported occurrences, approximately 20 percent of the cardinal deviations would be attributed to rounding, and approximately 80 percent of the cardinal deviations would be attributed to aircraft flying at unassigned cardinal altitudes or flying through cardinal altitudes assigned to other aircraft.

# APPENDIX B

## ANALYSIS OF ALTITUDE DEVIATIONS BY FLIGHT PATTERN

## APPENDIX B

# ANALYSIS OF ALTITUDE DEVIATIONS BY FLIGHT PATTERN

## INTRODUCTION

To obtain a better understanding of the mechanics of altitude deviations and their underlying causes, the reported deviations were sorted into groups having similar flight patterns before, during and after the commencement of altitude excursion. The resulting subpopulations were subjected to a series of analyses in a search for both differences and commonality among the groups.

The main text describes the basic flight patterns and the manner in which they are coded. This appendix expands upon that material.

Many different flight patterns can be defined in terms of the 6 flight phase states. However, only 10 distinct and complete flight patterns were actually observed in the data. Those flight patterns are itemized in Table B-1. Also indicated are the number of times each flight pattern was observed. In 128 reports, data describing the deviating aircraft's flight pattern were partially absent and they could not be categorized.

### Expected Differences Among Flight Pattern Groups

The population of altitude deviation incidents was divided into subpopulations because it was expected that there might be significant differences among the groups regarding: (1) the cause of the incident, (2) the probable magnitude of the deviations, (3) the manner in which the incident was resolved, or (4) the probable outcomes of the incident. A preliminary review of the data supported the possibility that there might be differences among the causes of the incidents based on flight pattern characteristics, and that significant differences in the other areas might also exist.

TABLE B-1. DISTRIBUTION OF REPORTS[a] BY FLIGHT PATTERN

| | Flight Pattern | | Number | Percent |
|---|---|---|---|---|
| | Actual | Expected | | |
| Failure-To-Level | A/A, A/A | A/TL, TL/L | 135 | 26.9 |
| | D/D, D/D | D/TL, TL/L | 116 | 23.1 |
| | | Subtotal | 251 | 50.0 |
| Failure-To-Maintain | M/TA, M/TA | L/L, L/L | 31 | 6.2 |
| | M/TD, M/TD | L/L, L/L | 66 | 13.1 |
| | | Subtotal | 97 | 19.3 |
| Failure-To-Attain | L/L, L/L | L/TD, TL/L | 6 | 1.2 |
| | L/L, D/D | L/TD, TL/L | 5 | 1.0 |
| | */*, D/D | L/TD, TL/L | 3 | 0.6 |
| | */*, L/L | L/TD, TL/L | 1 | 0.2 |
| | L/L, ** | L/TD, TL/L | 1 | 0.2 |
| | L/TD, D/D | L/TD, TL/L | 2 | 0.4 |
| | D/TL, L/L | D/D, TL/L | 2 | 0.4 |
| | L/L, L/L | L/TA, TL/L | 1 | 0.2 |
| | L/*, */* | L/TA, TL/L | 1 | 0.2 |
| | A/TL, L/L | A/A, TL/L | 5 | 1.0 |
| | A/TL, */* | A/A, TL/L | 1 | 0.2 |
| | A/A, A/A | A/TD, TL/L | 1 | 0.2 |
| | D/TA, L/L | D/D, TL/L | 2 | 0.4 |
| | */A, */* | */TD, TL/L | 1 | 0.2 |
| | | Subtotal | 32 | 6.4 |
| Unclassifiable(b) | - - | - - | 122 | 24.3 |
| | | TOTAL | 502 | 100.0 |

(a) Asterisks denote an unknown flight phase.

(b) These reports could not be classified into the three primary flight patterns for lack of data.

The expected differences in causation were based on an intuitive appraisal of the 3 flight pattern groupings. Failures-to-level are passive events suggesting errors of omission. By contrast, failures-to-maintain would appear to be errors of commission at least for those situations where the aircraft made a controlled departure from the assigned altitude. Failures-to-attain might result from a failure to depart for an assigned altitude, premature leveling before reaching an assigned altitude, or ascent or descent at too shallow an angle.

This study examines the flight pattern groups (failures-to-level, failures-to-maintain, and failures-to-attain) because there were too few observations for most individual flight patterns (e.g., there were only 5 A/TL, L/L incidents).

## APPROACH

This portion of the report addresses differences among flight pattern groups regarding: (1) the distribution of the computed magnitudes of the deviations, and (2) the causes of the deviations. The distributional characteristics of deviations in the various flight pattern groups were determined through the careful review and coding of 502 altitude deviation incidents. This methodology is explained in the main text.

A rigorous analysis of the causes of altitude deviations for the 3 primary flight pattern groups was not undertaken. However, as each of the 502 incidents was examined, some general impressions were formed and reinforced by extensive notetaking. These impressions may be regarded as hypotheses that may merit further study.

## FINDINGS

### Distributions

Distributions of altitude deviations were developed for failures-to-level, failures-to-maintain, failures-to-attain, and the unclassifiable reports. The observed distributions are shown in Figure B-1. The observed distributions can be approximated by a fitted geometric distribution of the form:

$$(1-Q)Q^{d-1}, \; d = 0, 1, 2, \ldots, 6$$

where

$Q$ is the probability of not detecting the deviation in any 1000-ft interval

$d$ is the magnitude of the deviation expressed in thousands of feet.

The equations from the geometric approximations of the observed distributions are shown in Table B-2. The significance of these distributions is discussed later.

TABLE B-2. FITTED GEOMETRIC APPROXIMATIONS TO OBSERVED ALTITUDE DEVIATION DISTRIBUTIONS

| Flight Pattern | Geometric Distribution |
|---|---|
| Failures-to-Level | $(0.73)(0.27)^{d-1}$ |
| Failures-to-Maintain | $(0.55)(0.45)^{d-1}$ |
| Failures-to-Attain | $(0.40)(0.60)^{d-1}$ |
| Unclassifiable | $(0.56)(0.44)^{d-1}$ |
| Weighted Combination[a] | $(0.60)(0.40)^{d-1}$ |

[a]Weighted by the number of reports for each flight pattern.

## Causation

During the investigation, the authors noted the reported occurrence of errors of omission versus errors of commission in the data set. This contrast was rooted in the earlier observation that failures-to-level and many

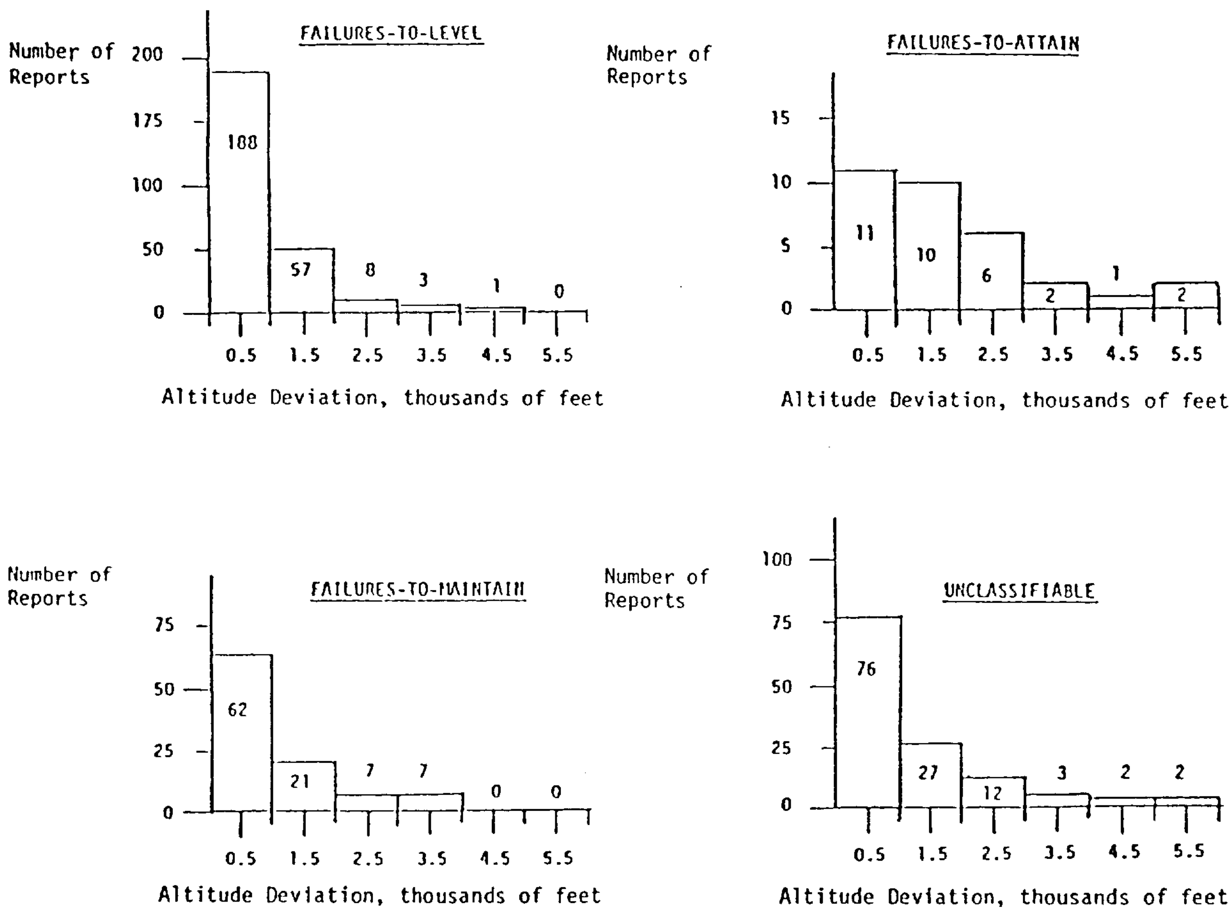


FIGURE B-1. OBSERVED DISTRIBUTIONS OF ALTITUDE DEVIATIONS BY FLIGHT PATTERN GROUPS failures-to-attain involve constant flight patterns whereas failures-to-maintain and some failures-to-attain are characterized by changing flight patterns.

A second line of inquiry involved a documentation of the information flight crews reported knowing during altitude deviations. Did any of the crew know the assigned altitude? Was someone aware of the aircraft's altitude? Were there communications difficulties? Was information lost or degraded?

Altimeter scanning, altitude alert, automatic pilot. - Many reporters indicated that an altitude deviation resulted from their failures to scan the altimeter with sufficient frequency. Often distraction was cited as a factor in such occurrences. Another reported factor was reliance on: (1) an altitude alert mechanism that malfunctioned or that was not heard or seen, or (2) an automatic pilot that failed to capture or hold. These factors were frequently associated with failures-to-level.

Information. Many respondents indicated that problems related to information processing and retention were associated with the occurrence of an altitude deviation. These problems included:

1. Mishearing a clearance
2. Not hearing a clearance
3. Mistaking another aircraft's clearance for one's own
4. Misinterpreting a clearance
5. Mistaking an "expect" clearance for an actual one*
6. Misreading an altimeter
7. Misreading a navigation chart.

Information related problems were most frequently associated with failures-to-maintain and failures-to-attain. The results were aircraft departing

*An "expect" clearance is one in which ATC tells a pilot that he can expect a clearance soon for a specified altitude.

their assigned altitudes without clearance, failing to leave altitudes for their assigned altitude, or leveling prematurely at an incorrect altitude.

Interestingly, the majority of reports coming from aircrews indicate that the reporter or another member of the flight crew knew the assigned altitude at some point before the deviation occurred. In some reports this information was said to have become degraded, forgotten, or not communicated to the flying pilot. In others the reporter indicated that the altimeter was not scanned with sufficient frequency to avert a deviation or the information was otherwise improperly applied. Note that a minority of reporters indicated they did not receive or understand the altitude clearance that a controller later indicated they had violated.

Profile descents. - Profile descents and altitude restrictions were often associated with failure-to-attain incidents. Reporters often indicated that navigation descent charts were misread or improperly related to the position of the aircraft. In other situations, reporters said they forgot an altitude restriction entirely, or until it was too late to make the restriction.

# DISCUSSION

## Distributions of Altitude Deviations by Flight Pattern

The general finding of this study is the fact that the exponential distribution (or its geometric analog) yields a good fit to the altitude deviations with different means for different subsets of the data. The differences between these mean values are examined below in terms of the time-to-detect interpretation previously described. The examination is given for three flight pattern groups: failures-to-level, failures-to-maintain, and failures-to-attain.

Rather than undermine the principal study conclusions, observed differences among the flight pattern groups amplify and support them. Each of the three subpopulations has a distribution that is approximately geometric, as can be observed in Figure B-1, but with different parameters. The differences in the parameters among the flight pattern groups can be meaningfully interpreted in terms of the time-to-detect model that has been suggested for the overall distribution of deviations.

The key to understanding the distributions shown in Table B-2 is analysis of the parameter Q. For example, Q = 0.27 for failures-to-level. This may be interpreted as follows: if a failure-to-level incident occurs, there is a 27 percent possibility that the aircraft will deviate 1000 feet without the deviation's being detected; if the deviation survives detection in the first 1000 feet, it has a 27 percent chance of surviving to 2000 feet without being detected, and so on.[a]

The distributions shown in Table B-2 are based on a distance measure. However, they can be translated into a time measure by dividing by a reference ascent/descent rate for deviating aircraft. (When the aircraft inappropriately maintained level flight, it is the typical ascent/descent rate for the aircraft that is of interest.)

Based on the preceding discussion, the findings shown in Table B-2 are reinterpreted as detection times in Table B-3. The detection time estimates are very sensitive to the assumed reference ascent/descent rates of aircraft. Variations in estimated detection times for the various flight patterns are discussed next.

Failures-to-level. - These altitude deviations may be detected by the flying pilot, nonflying crew, a controller, or by the aircrew of a second aircraft that comes into conflict with the deviating aircraft. Relatively few reports indicate that the altitude alert mechanism was the detection instrument. Such deviations are generally small and may not be deemed worth reporting.

[a] Conversely, the probability is 1-0.27 = 0.73 that the deviation will be detected the first 1000 feet.

TABLE B-3. ALTITUDE DEVIATION DETECTION TIMES, BY FLIGHT PATTERN AND REFERENCE ASCENT/DESCENT RATE

| Flight Pattern | Reference Ascent/Descent Rate $\mathring{h}$, feet/min | | |
|---|---|---|---|
| | 1000 | 1500 | 2000 |
| Probability of an Undetected Incident Surviving An Additional Minute Without Being Detected, P, percent[(a)] | | | |
| Failure-to-Level | 27 | 14 | 7 |
| Failure-to-Maintain | 45 | 30 | 20 |
| Failure-to-Attain | 60 | 47 | 36 |
| Unclassifiable | 44 | 30 | 20 |
| Combined | 40 | 25 | 16 |
| Half-Life of Deviation $\tau_{\frac{1}{2}}$, seconds[(b)] | | | |
| Failures-to-Level | 32 | 21 | 16 |
| Failure-to-Maintain | 52 | 34 | 26 |
| Failure-To-Attain | 82 | 54 | 41 |
| Unclassifiable | 51 | 34 | 26 |
| Combined | 45 | 30 | 22 |

[(a)]Computed using $P = \exp(-\mathring{h}/\bar{h})\mathrm{x}100$, where $\bar{h}$ denotes the mean altitude deviation shown in Table 3.

[(b)]Computed using $\tau_{\frac{1}{2}} = (\bar{h}/\mathring{h})\ln 2$, where $\bar{h}$ is shown in Table 3.

These reports may generally be regarded as those in which the primary mechanical control devices, the altitude alert and the automatic pilot, did not perform their usual role. Thus, the distribution reflects the speed and efficiency with which humans detected and exerted control over the altitude deviation problem.

It appears from the narratives that the flying pilot or other crew members often know the assigned altitude in failure-to-level incidents. Thus, the flying pilot as well as other human controllers may detect the deviation. Because of the large number of potential human detectors of a failure-to-level incident, the detection times may be relatively rapid when compared with other flight patterns.

In addition, the magnitude of failure-to-level deviations is generally understated because the computed measure is taken to be the difference between the altitude at detection and the inception altitude of the deviation. Data regarding the inception altitude were generally unavailable. Thus, the emergence point was generally used to compute the magnitude of the deviation. If data describing the inception point were available, the average calculated deviation would be at least a few hundred feet larger.

Failures-to-maintain. - These incidents often involve pilots who become convinced that they are no longer assigned to the altitude where they are flying. In these situations, the pilot effectively neutralizes the mechanical constraints on the deviation -- the altitude alert mechanism and the automatic pilot. Moreover, he does not perform his usual role as the primary human detector of altitude deviations. It may be for these reasons that failures-to-maintain seem to persist for a longer time than failures-to-level.

Failures-to-attain. - The magnitude of the altitude deviation is roughly proportional to the existence of the deviation over time for failures-to-attain (just as it is for failures-to-level and failures-to-maintain). The time duration of the failure-to-attain incident is defined as the difference between the detection time and the inception time. However, the distance used to compute the deviation's time to detect is the distance between the flight altitude at the time of detection and the assigned altitude at the emergence point. The mean altitude deviation is considerably larger for failures-to-attain, than for failures-to-level and failures-to-maintain.

Failures-to-attain generally involve missed crossing restrictions on profile descents often because of misread or misunderstood navigation charts. As with failures-to-maintain, the flying pilot may be unaware of the altitude deviation because he believes (because of the false reading of a chart or instrument) that he is at the correct altitude. Moreover, many of these incidents involve clearances provided only on the navigation charts or approach plates -- not verbally by the controller. The restriction may simply be forgotten.

Altitude deviations associated with failures-to-level and failures-to-maintain are usually detected by scanning an altimeter or a data block on a scope without referring to the deviating aircraft's horizontal position (i.e., it is known that an aircraft should not be above or below a specified altitude regardless of its horizontal position). By contrast, the detection of a failure-to-attain involves a correlation of an aircraft's altitude with its horizontal position.

Further, it may be unclear to a controller or nonflying crew member that an altitude restriction has been forgotten because ascent/descent rates vary among aircraft and pilots. The point where ascent or descent should commence is correspondingly vague. It is possible for a nonflying pilot or controller not to recognize this type of deviation until it has persisted for a considerable time.

Taken together, these factors are believed to account for the relatively large mean altitude deviations obtained for the failure-to-attain flight pattern.

Unclassifiable. - These reports generally involve narratives that are too sketchy to classify according to flight pattern. As such, this group is likely to be an amalgam of the other flight pattern groups. The statistical characteristics of this group would be expected to be intermediate to those of the other groups. This is seen to be the case for the results shown in Table B-3.

## Causation

As was noted earlier, the causes of altitude deviation incidents were not analyzed in a rigorous fashion. Only general impressions are reported. On that basis the following assertions are made:

1. Most altitude deviations in the database involve a flight pattern where the flight path should have changed to accommodate an altitude assignment but did not. Thus, there is evidence of an error of omission. The most frequently cited reasons for these errors of omission are fai ure to monitor the altimeter and excessive reliance on an altitude alert mechanism or automatic pilot. Distraction is also said to play a role as well as difficulties related to information transfer, retention, or degradation.
2. A minority of altitude deviations involve a changing flight pattern where the aircraft's flight phase inappropriately changed resulting in an altitude deviation. This suggests an error of commission. The most frequently cited reasons for these occurrences are information related. These include misreading altimeters, other instruments, or a navigation chart; misunderstanding a clearance, and so on. A few of these cases do not involve errors of commission. Instead they manifest undetected departure, reliance on a malfunctioning automatic pilot, uncontrolled ascent/descent in weather, and assorted other occurrences.

Although these findings hold in a general sense, there are reports in the database that do not fit these patterns. Thus, one must be careful to avoid over generalizing these findings that are best regarded as hypotheses rather than firm conclusions.

# CONCLUSIONS

The 805 altitude deviations examined in this study show a remarkable consistency. Attempts to subdivide the population into meaningful subgroups served to underscore the commonalities shared by the subgroups. Most importantly, the altitude deviations of each flight pattern group are found to be well-represented by exponential distributions. However, some limited differences were detected among flight pattern groups. Geometric distributions could be constructed that closely approximated the observed distribution of deviations for each flight pattern but their half-lives differed. The differences in half-lives is amenable to explanation in terms of a time-to-detect analytical framework. The differences among the mean altitude deviations and corresponding half-lives are postulated to reflect variations in the number of human control agents involved in surveillance and the difficulty of the surveillance task. It is believed that the ease with which the inception point of an altitude deviation can be identified varies among flight pattern groups and may be a particularly important determinant of detection speed.

During the research effort some basic hypotheses were developed regarding differences in the causes of altitude deviations among flight pattern groups. The following hypotheses merit further investigation: failures-to-level result from low scan rates on instruments, distraction, and excessive reliance on autopilots and altitude alert mechanisms; failures-to-maintain and failures-to-attain relate to information processing problems, including miscommunication, misreading of navigation charts, misreading of instruments, and forgetting ATC assignments or crossing restrictions.

# APPENDIX C

## MATHEMATICAL DERIVATIONS

APPENDIX C

## MATHEMATICAL DERIVATIONS

### A MATHEMATICAL DERIVATION OF EXPONENTIALLY DISTRIBUTED DETECTION TIMES

The following argument is intended to provide direct support for an exponential distribution for detection times of altitude deviations. Consider a population of altitude deviations. It is assumed that each deviation is detected at some time, and that the mean time to detect a deviation is given by $\tau$. It is convenient to measure all time intervals in units of this mean time. Now suppose that at time 0 an altitude deviation exists for a particular aircraft, and consider the probability that the deviation is still undetected at time $t/\tau$. Note that if $t/\tau$ is made sufficiently small, the deviation is not likely to be detected in this small time interval. A deviation that is undetected at the present time is not likely to be detected in the next second; it is still less likely to be detected in the next millisecond, etc. This suggests that by making $t/\tau$ sufficiently small, the probability that the deviation is still undetected can be made arbitrarily close to 1.0. A simple representation of this probability takes the following form: $Q = 1-(t/\tau)$. This expression clearly shows that the probability that the deviation is not detected is arbitrarily close to 1 as $t/\tau$ is made arbitrarily small.

Next suppose that the altitude deviation, in fact, has not been detected at a specific time $t/\tau$, and suppose that the time interval $t/\tau$ is subdivided into n equal subintervals. Because the deviation is not detected at time $t/\tau$, it cannot have been detected during any of the n earlier time intervals, each of which has a duration of $(\frac{t}{n})\ (\frac{1}{\tau})$. In probability terms this means that Q can also be written as a product: $Q = (1-\frac{t}{n} \cdot \frac{1}{\tau})^n$. This expression simply indicates that the deviation was not detected in any of the n time intervals, each of length $(\frac{t}{n})\ (\frac{1}{\tau})$. Finally, by letting n become arbitrarily large, it is found that $Q = e^{-t/\tau}$. From this result, it follows that $P = 1-Q = 1-e^{-t/\tau}$, and this expression represents the probability that the deviation is detected in the interval $(0,t/\tau)$. The probability that the deviation is detected in some infinitesimal time interval is then given by $dP = (1/\tau)e^{-t/\tau}dt$. This form is the customary mathematical expression for an exponential distribution with mean $\tau$.

## LINEARIZED FORM FOR EXPONENTIALLY DISTRIBUTED ALTITUDE DEVIATIONS

The exponential distribution for an altitude deviation $\Delta h$ may be written as follows:

$$f(\Delta h) = (1/\delta)\ \exp(-\Delta h/\delta),\quad \Delta h \geq 0, \tag{C-1}$$

where the parameter $\delta$ denotes the mean altitude deviation for the distribution. The integration of Equation (C-1) to the left of $\Delta h$ shows that the area in the left tail of the exponential distribution is given by $F(\Delta h) = 1-\exp(-\Delta h/\delta)$, where $F(\Delta h)$ represents the cumulative distribution function. By solving for $\exp(-\Delta h/\delta)$ and taking logarithms, it follows that

$$\ln\left(\frac{1}{1-F(\Delta h)}\right) = (1/\delta)\ \Delta h. \tag{C-2}$$

This expression shows that if the left side is plotted against $\Delta h$, the result is a straight line through the origin with a slope equal to $1/\delta$.

The cumulated fraction of the altitude deviations less than $\Delta h$ serves as an estimate of $F(\Delta h)$. If these estimates are substituted into the left side of Equation (C-2) and plotted versus $\Delta h$, then the resulting points will fall approximately on a straight line with a theoretical slope given by $1/\delta$, provided the data are represented by an exponential distribution. The slope $\delta$ can be estimated by fitting the data with a regression line through the origin. The reciprocal of the slope of the regression line then provides a numerical estimate of the mean altitude deviation.

## Detection Times Proportional to Altitude Deviations are Exponentially Distributed

Let altitude deviations $\Delta h$ be exponentially distributed with mean $\delta$. Then the probability that an altitude deviation is less than $\Delta h$ is given by $f(\Delta h) = 1-\exp(-\Delta h/\delta)$. Now suppose that the detection time for an altitude deviation is given by $\Delta h/\mathring{h}$, where $\mathring{h}$ denotes a constant rate of change of altitude for the aircraft. Consider the probability that the detection time is less than some number k. This may be written as $P\{t\leq k\}$. By substitution it follows that

$$P\{t\leq k\} = P\{\Delta h/\mathring{h}\leq k\} = P\{\Delta h\leq k\mathring{h}\} = F(k\mathring{h}).$$

The right-most expression is seen to be the cumulative distribution function evaluated at $k\mathring{h}$, so that $F(k\mathring{h}) = 1-\exp(-k\mathring{h}/\delta)$. This result may be rearranged to obtain

$$P\{t\leq k\} = 1-\exp(-k/(\delta/\mathring{h})),$$

and it is seen from the form of this expression that the detection time t is exponentially distributed with a mean detection time given by $\delta/\mathring{h}$. The cumulative distribution function can then be written as follows:

$$F_T(t) = 1-\exp(-t/\tau), \qquad \text{(C-3)}$$

where $\tau$ denotes the mean time to detection and is given by $\tau=\delta/\mathring{h}$.

## Half-Lives for Exponentially Distributed Altitude Deviations

The half-life $t_{1/2}$ of an altitude deviation is obtained from Equation (C-3) by setting $F_T(t) = 1/2$ and solving the resulting expression for t. The solution is found to be:

$$t_{1/2} = \tau \ln 2.$$

Thus, the half-life of an exponentially distributed altitude deviation is given by $\tau \ln 2$, and is approximately 70 percent of the mean time to detection for the distribution. In terms of the mean altitude deviation $\Delta$ and a constant rate of change of altitude $\mathring{h}$, the half-life is given by

$$t_{1/2} = (\Delta/\mathring{h}) \ln 2.$$

## Confidence Intervals for Means of Exponentially Distributed Altitude Deviations

Let $\hat{\tau}$ denote an estimate, based on f measurements, of the mean time $\tau$ of an exponential distribution. It may be shown that the ratio $\hat{\tau}/\tau$ is distributed as a $\chi^2$ deviate with 2f degrees of freedom.[1] It follows that

$$P\{\chi^2_{0.025}/2f < \hat{\tau}/\tau < \chi^2_{0.975}/2f\} = 0.95,$$

where $\chi^2_p$ denotes the fractile of the $\chi^2$ distribution having the fractional area p to its left. The preceding expression may be rearranged to provide a 95 percent confidence interval for $\tau$:

$$P\{(\hat{\tau}/F_2) < \tau < (\hat{\tau}/F_1)\},$$

where $F_1$ and $F_2$ denote $\chi^2_{0.025}/2f$ and $\chi^2_{0.975}/2f$, respectively.

The estimates for $\hat{\tau}$ are obtained by using the reciprocals of the slopes of the regression lines, constrained to pass through the origin, that are fitted to the various partitionings of the 502 altitude deviations. The factors $F_1$ and $F_2$ are obtained using the following large-sample approximations:[2]

$$\chi^2_p/2f = (1/(4f))(\sqrt{4f-1} + u_p)^2,$$

where p = 0.025 and 0.975 for $F_1$ and $F_2$, and $u_p$ denotes the fractile of the Normal distribution with a fractional area p to its left.

Table C-1 shows a listing of the factors $F_1$ and $F_2$ for the various partitionings of the set of 502 altitude deviations. The lower and upper 95 percent confidence limits for the means shown in column 3 are obtained by dividing the means by $F_2$ and $F_1$, respectively. The results are shown in Table 3.

## Statistical Tests of Significance Among Mean Altitude Deviations

Table C-2 shows numerical results for testing the statistical significance of the differences among the mean altitude deviations for the subgroups associated with the partitionings of the 502 altitude deviations. The mean

TABLE C-1. CONFIDENCE LIMIT FACTORS

| Partitioning | f | Mean Altitude Deviation, ft | Confidence Limit Factors | |
|---|---|---|---|---|
| | | | $F_1$ | $F_2$ |
| Failure-to-Level | 251 | 773 | 0.88 | 1.13 |
| Failure-to-Maintain | 97 | 1237 | 0.81 | 1.21 |
| Failure-to-Attain | 32 | 1964 | 0.68 | 1.37 |
| Unclassifiable | 122 | 1225 | 0.83 | 1.18 |
| Pilot Reports | 297 | 973 | 0.89 | 1.12 |
| Controller Reports | 190 | 1252 | 0.86 | 1.15 |
| Pilot and Controller | 15 | 1027 | 0.55 | 1.55 |
| No Military Aircraft Involved | 437 | 1078 | 0.91 | 1.10 |
| Military Aircraft Involved | 65 | 1122 | 0.77 | 1.25 |
| Evasive Action Taken | 111 | 1197 | 0.82 | 1.19 |
| Unknown Action or None | 63 | 1163 | 0.76 | 1.26 |
| No Conflict | 328 | 989 | 0.89 | 1.11 |
| Combined | 502 | 1080 | 0.91 | 1.09 |

altitude deviations shown in Column 3 are ranked in decreasing order. Because these means are associated with exponential distributions it is assumed that the estimated means are chi-square distributed with 2f degrees of freedom, where f is equal to n-1, and n is equal to the number of reports involved in the mean altitude deviation.

Comparisons among means are made by taking ratios of the larger means to the smallest mean within each partitioning. These ratios are shown in column 5 and are taken to be F-distributed with $2f_1$, and $2f_2$ degrees of freedom. The critical values for the 95 percent fractiles of the F-distribution are shown in column 6 and are computed using a large sample approximation.(3) If the ratio of the mean altitude deviations in column 5 exceeds the critical

TABLE C-2. TESTS FOR STATISTICAL SIGNIFICANCE AMONG MEAN ALTITUDE DEVIATIONS

| Partitioned By | Subgroup | Mean Altitude Deviation(1), ft. | Degrees of Freedom, 2f(2) | Mean Altitude Ratio(3) | Computed 95 Percent F-ratio(4) | Statistically Significant Result(5) |
|---|---|---|---|---|---|---|
| Flight Pattern | Failure-to-Attain | 1960 | 62 | 2.55 | 1.34 | Yes |
| | Failure-to-Maintain | 1240 | 192 | 1.61 | 1.21 | Yes |
| | Unclassifiable | 1230 | 242 | 1.60 | 1.20 | Yes |
| | Failure-to-Level | 770 | 500 | 1.00 | -- | -- |
| Reporter | Controller | 1250 | 378 | 1.29 | 1.16 | Yes |
| | Pilot and Controller | 1030 | 28 | 1.06 | 1.49 | No |
| | Pilot | 970 | 592 | 1.00 | -- | -- |
| Military Aircraft Involved | Involvement | 1120 | 128 | 1.04 | 1.23 | No |
| | No Involvement | 1080 | 872 | 1.00 | -- | -- |
| Outcome | Evasive Action Taken | 1200 | 220 | 1.21 | 1.19 | Yes |
| | Unknown Action or None | 1160 | 124 | 1.17 | 1.24 | No |
| | No Conflict | 990 | 654 | 1.00 | -- | -- |

(1) From Table 3, rearranged in order of mean altitude deviation.

(2) Computed using $2f = 2n-2$, where n is the number of reports.

(3) Ratios are formed with the larger mean in the numerator, the smaller mean in denominator.

(4) Computed using $\log_{10} F = 1.4287/\sqrt{h-0.95}-0.681(f_1^{-1}-f_2^{-1})$,

where $h^{-1} = (1/2)(f_1^{-1}+f_2^{-1})$. See Reference (3).

(5) Results are statistically significant at 5 percent level of significance whenever ratio in Column 5 exceeds entry in Column 6.

F-ratio in column 6, it is concluded that the means differ statistically at the 5 percent level of significance.

The last column of the table shows that the mean altitude deviations are statistically larger for each flight pattern relative to the mean altitude deviation for the failure-to-level subgroup. Similarly, it is seen that the mean altitude deviation associated with controller reports statistically exceeds that associated with pilot reports. The mean altitude deviation for reports involving military aircraft does not differ at the 5 percent level of significance from the mean altitude deviation for reports not involving military aircraft. The final portion of the table shows that the mean altitude deviation for reports involving evasive actions is barely significant (mean ratio of 1.21 versus critical F-ratio of 1.19), relative to the mean altitude deviation for No Conflict reports that typically involved single aircraft.

## Relation Between the Geometric and Exponential Distributions

Both the geometric and exponential distributions were used in analyzing the magnitudes of the altitude deviations. The following expression shows the relation between these two distributions:

$$pq^{k-1} = (1-e^{-1/\tau})(e^{-1/\tau})^{k-1}, \ k = 1, 2, \ldots,$$

where the left side shows a term of the geometric distribution with $p = 1-q$ and $0<q<1$. The correspondence between the two distributions is seen by equating $q$ with $e^{-1/\tau}$, where $\tau>0$ denotes the mean of the exponential distribution. This equality shows that $(1/\tau) = \ln(1/q)$ so that the exponential distribution can be expressed in terms of the geometric parameter $q$ as follows:

$$f(k) = \ln(1/q)e^{-k \ln(1/q)}, \ k = 1, 2, \ldots .$$

With this relation it can be shown that the area under the exponential distribution between $k-1$ and $k$ is equal to $pq^{k-1}$, $k = 1, 2, \ldots$ .

As an application consider an exponential distribution with mean $\tau =$ 1000 feet that is to be represented by a geometric distribution with intervals of 100 feet. Because $k = 1, 2, \ldots$ must correspond to 100,200,... feet, it follows that $\tau$ = 1000 feet corresponds to k = 10, so that $\tau$ is measured in units of 100 feet and has a magnitude of 10. With $\tau$ = 10, it is seen that $q = e^{-1/10} = 0.9048$, and p = 0.0952, so the geometric representation is given by

$$pq^{k-1} = (0.0952)(0.9048)^{k-1}.$$

If the geometric representation has intervals of 1000 feet, then the rescaled value of $\tau$ is 1.0. In this case, the geometric distribution takes the form:

$$pq^{k-1} = (1-\frac{1}{e})(\frac{1}{e})^{k-1}.$$

Table C-3 shows the observed and expected numbers of reports based on equation (C-1). The table shows excellent agreement between the observed number of reports and the geometric distribution given above.

TABLE C-3. OBSERVED AND EXPECTED NUMBER OF REPORTS USING GEOMETRIC DISTRIBUTION AT 1000-FT INTERVALS

| Upper Limit of Altitude Deviation k, Thousands of Feet | Number of Reports | | Chi-Square Component, $(O-E)^2/E$ |
|---|---|---|---|
| | Observed(1) O | Expected(2) E | |
| 1 | 337 | 317.3 | 1.22 |
| 2 | 109 | 116.7 | 0.51 |
| 3 | 33 | 42.9 | 2.28 |
| 4 | 15 | 15.8 | 0.04 |
| 5 | 4 | 5.8 | 0.56 |
| 6+ | 4 | 3.5 | 0.07 |
| Total | 502 | 502.0 | 4.68(3) |

(1) Source: Table D-1

(2) Computed using $502(1-(1/e))(1/e)^{k-1}$

(3) Chi-Square value of 4.68, with 5 degrees of freedom, is not satistically significant at the 95 percent level, so the observed results are consistent with the geometric distribution at 1000-ft intervals.

## REFERENCES


1. Mann, N. R., Schafer, R. E., Singpurwalla, N. D., Methods for Statistical Analysis of Reliability and Life Data, John Wiley and Sons, Inc., New York, 1974, p. 165.

2. Hald, A., Statistical Theory With Engineering Applications, John Wiley and Sons, Inc., New York, 1952, p. 258.

3. Hald, A., Statistical Tables and Formulas, John Wiley and Sons, Inc., New York, 1952, p. 51.

# APPENDIX D

## SEARCH STRATEGY, ACCESSION NUMBERS, AND DATA LISTING FOR ALTITUDE DEVIATION REPORTS

## APPENDIX D

## SEARCH STRATEGY, ACCESSION NUMBER, AND DATA LISTING FOR ALTITUDE DEVIATION REPORTS

An inclusive search strategy was used to obtain the reports for this study. The following keywords were used: altitude deviation, altitude excursion, altitude overshoot, altitude undershoot, deviation from clearance, unauthorized climb, and unauthorized descent. The detailed search strategy given below is taken from the computer printout:

```
AVIATION SAFETY REPORTING SYSTEM

LAST UPDATE 08/27/80
WITH 12563 REPORTS.

ENTER YOUR REQUESTS ONE AT A TIME
  1/ XEQ,ATTACH,SAVEPFL,SEARCH,ID=HECHT
ENTER YOUR REQUEST
  1/
 AT CY= 003 SN=SHARED    /X ALTBUST

  1/ ALTITUDE D*ALL
       1037 REPORTS
      21 TERMS WITH YOUR STEM WERE COMBINED
  2/ ALTITUDE EXCURSION
         29 REPORTS
  3/ ALTITUDE OV*ALL
         80 REPORTS
       3 TERMS WITH YOUR STEM WERE COMBINED
  4/ ALTITUDE UN*ALL
         20 REPORTS
       2 TERMS WITH YOUR STEM WERE COMBINED
  5/ ALTITUDEDE*ALL
          4 REPORTS
       3 TERMS WITH YOUR STEM WERE COMBINED
  6/ ALTITUDEOV*ALL
          4 REPORTS
       1 TERMS WITH YOUR STEM WERE COMBINED
  7/ ALTITUDEUN*ALL
          2 REPORTS
       1 TERMS WITH YOUR STEM WERE COMBINED
  8/ DEVIATION FROM CLEARANCE/A*ALL
          6 REPORTS
       3 TERMS WITH YOUR STEM WERE COMBINED
  9/ DEVIATION/AL*ALL
          1 REPORT
       1 TERMS WITH YOUR STEM WERE COMBINED

 10/ UNAUTHORIZED AL*ALL
         69 REPORTS
       3 TERMS WITH YOUR STEM WERE COMBINED
 11/ UNAUTHORIZEDCL*ALL
          2 REPORTS
       2 TERMS WITH YOUR STEM WERE COMBINED
 12/ UNAUTHORIZED CL*ALL
        106 REPORTS
       7 TERMS WITH YOUR STEM WERE COMBINED
 13/ UNAUTHORIZED DE*ALL
        102 REPORTS
       4 TERMS WITH YOUR STEM WERE COMBINED
 14/ ( 1 0 2 0 3 0 4 0 5 0 6 0 7 0 8 0 9 0 10 0 11 0 12 0 13 )
```

Table D-1 shows the distribution of the computed altitude deviations for 508 ASRS reports. With the exclusion of the six largest deviations, between 7000 ft and 16,500 ft, the remaining 502 altitude deviations constitute the primary data for this report.

TABLE D-1. DISTRIBUTION OF COMPUTER ALTITUDE DEVIATIONS FOR 508 ASRS REPORTS

| Altitude Deviation, feet | Number of Reports | Altitude Deviation, feet | Number of Reports | Altitude Deviation, feet | Number of Reports |
|---|---|---|---|---|---|
| 100 | 2 | 1400 | 6 | 3000 | 17 |
| 200 | 10 | 1500 | 19 | 3200 | 1 |
| 300 | 12 | 1600 | 1 | 3300 | 1 |
| 350 | 1 | 1700 | 3 | 3500 | 1 |
| 400 | 33 | 1800 | 4 | 4000 | 12 |
| 480 | 1 | 1900 | 1 | 4700 | 1 |
| 500 | 50 | 1950 | 1 | 4800 | 1 |
| 600 | 34 | 2000 | 44 | 5000 | 2 |
| 700 | 33 | 2100 | 1 | 5400 | 1 |
| 800 | 21 | 2200 | 1 | 6000 | 3 |
| 900 | 13 | 2300 | 2 | 7000 | 1* |
| 1000 | 122 | 2400 | 2 | 10000 | 2* |
| 1100 | 6 | 2500 | 7 | 11000 | 1* |
| 1200 | 11 | 2600 | 1 | 13000 | 1* |
| 1300 | 13 | 2700 | 2 | 16500 | 1* |

*These altitude deviations are excluded from the statistical analyses presented in the main body of this report.

The attached listing shows in Column 1 the accession numbers of the ASRS reports used in this study. The numbers shown in Column 2 are the sequence numbers of those reports that contained numerical information provided by the reporter (listed in Column 3) for the flight altitude (shown in Column 4) and the assigned altitude (shown in Column 5). The difference between these two numbers is taken to be the altitude deviation. This difference is shown in Column 6 with a negative sign for those deviations in which the flight altitude is below the assigned altitude. Column 7 gives an assessment of whether the computed altitude deviation in Column 5 is a lower bound to the actual altitude deviation or whether it represents the maximum altitude deviation. If level flight occurred at the incorrect altitude, the flight pattern group is shown in Column 8. The improper flight altitude where a deviating aircraft flew level is shown in Column 9 for the subset of incidents where this occurred. In Column 10 various attributes related to evasive action incidents are listed. Incidents involving military aircraft are indicated in Column 11.

| ACCESSION NUMBER | ID NUMBER | REPORTER | FLIGHT ALTITUDE | ASSIGNED ALTITUDE | DEVIATION | BOUND | FLIGHT PATTERN | LEVEL DEVIATION | EVASIVE ACTION | MILITARY INVOLVED |
|---|---|---|---|---|---|---|---|---|---|---|
| 8640 | 1.0 | AIRCREW | 14000 | 16000 | -2000 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 8554 | 2.0 | AIRCREW | 6500 | 10000 | -3500 | MAXIMUM | FAIL-LEVEL | 0 | NO TIME | YES |
| 8659 | 3.0 | AIRCREW | 5400 | 5000 | 400 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 8662 | 4.0 | AIRCREW | 5900 | 3000 | 3000 | MAXIMUM | FAIL-ATTAIN | 6000 | NO CONFLICT | NO |
| 8735 | 6.0 | ATC | 4900 | 4000 | 900 | LOWER | UNCLASSIFIED | 0 | UNKNOWN | YES |
| 8810 | 12.0 | ATC | 9800 | 9000 | 800 | LOWER | FAIL-LEVEL | 0 | YES | YES |
| 8863 | 15.0 | AIRCREW | 7000 | 8000 | -1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 8868 | 16.0 | AIRCREW | 0 | 0 | -100 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 8870 | 17.0 | AIRCREW | 3500 | 4000 | -500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 8919 | 20.0 | AIRCREW | 9200 | 11000 | -1800 | LOWER | FAIL-MAINTAIN | 9200 | NO CONFLICT | NO |
| 8912 | 21.0 | AIRCREW | 32000 | 31000 | 1000 | LOWER | FAIL-MAINTAIN | 0 | NONE | NO |
| 8920 | 22.0 | ATC | 23000 | 21000 | 2000 | MAXIMUM | UNCLASSIFIED | 23000 | NONE | YES |
| 8922 | 23.0 | AIRCREW | 22000 | 24000 | -2000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 8927 | 24.0 | ATC | 37000 | 33000 | 4000 | MAXIMUM | UNCLASSIFIED | 37000 | NO CONFLICT | NO |
| 8930 | 25.0 | ATC | 14100 | 15000 | -900 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 8931 | 26.0 | AIRCREW | 23000 | 21000 | 2000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | YES |
| 8939 | 28.0 | ATC | 4600 | 5000 | -400 | LOWER | FAIL-MAINTAIN | 0 | NONE | NO |
| 8941 | 30.0 | AIRCREW | 7000 | 5000 | 2000 | LOWER | FAIL-LEVEL | 0 | ATC | NO |
| 8952 | 31.0 | AIRCREW | 6700 | 6000 | 700 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 8954 | 32.0 | AIRCREW | 17800 | 19000 | -1200 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 8965 | 33.0 | ATC | 5500 | 6000 | -500 | LOWER | FAIL-LEVEL | 0 | ATC | NO |
| 8968 | 34.0 | ATC | 33000 | 37000 | -4000 | MAXIMUM | UNCLASSIFIED | 33000 | ATC | NO |
| 8991 | 36.0 | AIRCREW | 15800 | 15000 | 800 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 8997 | 37.0 | AIRCREW | 19500 | 19000 | 500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 8994 | 39.0 | AIRCREW | 4300 | 5000 | -700 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9023 | 40.0 | AIRCREW | 6400 | 6000 | 400 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9025 | 41.0 | ATC | 12000 | 10000 | 2000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9029 | 43.0 | AIRCREW | 12000 | 11000 | 1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9036 | 44.0 | AIRCREW | 31500 | 29000 | 2500 | LOWER | FAIL-ATTAIN | 0 | NO CONFLICT | NO |
| 9069 | 46.0 | ATC | 4700 | 5000 | -300 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 9076 | 47.0 | AIRCREW | 21000 | 23000 | -2000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9083 | 48.0 | ATC | 14500 | 14000 | 500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9116 | 50.0 | ATC | 20600 | 20000 | 600 | LOWER | FAIL-MAINTAIN | 0 | UNKNOWN | NO |
| 9127 | 52.0 | AIRCREW | 22200 | 23000 | -800 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 9129 | 53.0 | ATC | 5700 | 6000 | -300 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9132 | 54.0 | ATC | 4000 | 3000 | 1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9134 | 55.0 | AIRCREW | 6900 | 6000 | 900 | LOWER | FAIL-LEVEL | 0 | YES | NO |
| 9137 | 56.0 | AIRCREW | 11700 | 12000 | -200 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9143 | 57.0 | AIRCREW | 9000 | 7000 | 2000 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 9145 | 58.0 | AIRCREW | 9000 | 8000 | 1000 | MAXIMUM | FAIL-LEVEL | 0 | YES | NO |
| 9192 | 61.0 | AIRCREW | 20200 | 21000 | -800 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9197 | 63.0 | ATC | 14700 | 14000 | 700 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 9226 | 66.0 | AIRCREW | 4000 | 3000 | 1000 | MAXIMUM | FAIL-ATTAIN | 4000 | YES | NO |
| 9229 | 67.0 | AIRCREW | 10700 | 12000 | -1300 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |

| ACCESSION NUMBER | ID NUMBER | REPORTER | FLIGHT ALTITUDE | ASSIGNED ALTITUDE | DEVIATION | BOUND | FLIGHT PATTERN | LEVEL DEVIATION | EVASIVE ACTION | MILITARY INVOLVED |
|---|---|---|---|---|---|---|---|---|---|---|
| 9231 | 68.0 | AIRCREW | 21500 | 17500 | 4000 | LOWER | FAIL-MAINTAIN | 21500 | NO CONFLICT | NO |
| 9258 | 71.0 | AIRCREW | 10000 | 7000 | 3000 | LOWER | FAIL-LEVEL | 0 | NONE | NO |
| 9270 | 72.0 | AIRCREW | 0 | 2500 | -2500 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9287 | 73.0 | AIRCREW | 12000 | 11000 | 1000 | MAXIMUM | FAIL-LEVEL | 12000 | NO CONFLICT | NO |
| 9365 | 75.0 | ATC | 4300 | 3000 | 1300 | LOWER | UNCLASSIFIED | 0 | NONE | YES |
| 9395 | 76.0 | ATC | 5100 | 5700 | -600 | LOWER | UNCLASSIFIED | 0 | YES | YES |
| 9416 | 77.1 | ATC | 9000 | 10000 | -1000 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 9416 | 77.2 | ATC | 23500 | 24000 | -500 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9379 | 80.0 | ATC | 6100 | 7000 | -900 | LOWER | FAIL-MAINTAIN | 0 | NONE | NO |
| 9464 | 81.0 | AIRCREW | 11500 | 11000 | 500 | LOWER | FAIL-MAINTAIN | 0 | ATC | NO |
| 9492 | 82.0 | AIRCREW | 4300 | 5500 | -1200 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 9534 | 85.0 | AIRCREW | 13600 | 14000 | -400 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9544 | 86.0 | ATC | 23400 | 21000 | 2400 | LOWER | FAIL-LEVEL | 0 | UNKNOWN | YES |
| 9548 | 67.0 | ATC | 4300 | 7000 | -2700 | LOWER | FAIL-MAINTAIN | 0 | ATC | NO |
| 9552 | 88.0 | AIRCREW | 9000 | 12000 | -3000 | MAXIMUM | UNCLASSIFIED | 9000 | NO CONFLICT | NO |
| 9555 | 89.0 | AIRCREW | 10700 | 12000 | -1300 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 9581 | 90.0 | AIRCREW | 17400 | 17000 | 400 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 9585 | 91.0 | AIRCREW | 8000 | 9000 | -1000 | MAXIMUM | FAIL-MAINTAIN | 8000 | NO CONFLICT | NO |
| 9603 | 92.0 | ATC | 13000 | 10000 | 3000 | LOWER | FAIL-ATTAIN | 0 | NO CONFLICT | NO |
| 9631 | 95.0 | AIRCREW | 12000 | 13000 | -1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9659 | 98.0 | ATC | 11000 | 10000 | 1000 | LOWER | FAIL-ATTAIN | 0 | NO CONFLICT | NO |
| 9677 | 99.0 | AIRCREW | 10500 | 11000 | -500 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 9683 | 100.0 | AIRCREW | 6400 | 5000 | 1400 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9688 | 102.0 | AIR-ATC | 4000 | 6000 | -2000 | LOWER | UNCLASSIFIED | 0 | ATC | NO |
| 9729 | 104.0 | AIRCREW | 6000 | 7000 | -1000 | MAXIMUM | FAIL-LEVEL | 6000 | NO CONFLICT | NO |
| 9765 | 108.0 | AIRCREW | 6000 | 7000 | -1000 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 9773 | 109.0 | AIRCREW | 5600 | 6000 | -400 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 9784 | 110.0 | ATC | 10000 | 9000 | 1000 | LOWER | FAIL-LEVEL | 0 | NO TIME | YES |
| 9793 | 112.0 | ATC | 29000 | 28000 | 1000 | MAXIMUM | UNCLASSIFIED | 29000 | NO CONFLICT | NO |
| 9797 | 113.0 | AIRCREW | 24000 | 23000 | 1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9803 | 114.0 | ATC | 34500 | 33000 | 1500 | LOWER | FAIL-ATTAIN | 0 | ATC | YES |
| 9812 | 115.0 | ATC | 29000 | 28000 | 1000 | MAXIMUM | FAIL-LEVEL | 29000 | NO CONFLICT | NO |
| 9820 | 116.0 | ATC | 9000 | 3000 | 6000 | MAXIMUM | UNCLASSIFIED | 9000 | NO CONFLICT | NO |
| 9845 | 117.0 | ATC | 7000 | 7500 | -500 | LOWER | UNCLASSIFIED | 0 | NONE | NO |
| 9873 | 118.0 | AIRCREW | 2500 | 3000 | -500 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9901 | 120.0 | ATC | 20000 | 24000 | -4000 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 9914 | 121.0 | ATC | 12000 | 10000 | 2000 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 9929 | 122.0 | AIRCREW | 6700 | 6000 | 700 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9932 | 123.0 | AIRCREW | 13400 | 13000 | 400 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 9934 | 124.0 | AIRCREW | 5000 | 4000 | 1000 | MAXIMUM | FAIL-LEVEL | 5000 | NO CONFLICT | NO |
| 9940 | 125.0 | AIRCREW | 9500 | 10000 | -500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 9952 | 126.0 | ATC | 5000 | 11000 | -6000 | MAXIMUM | FAIL-ATTAIN | 5000 | ATC | NO |
| 9994 | 129.0 | AIRCREW | 3000 | 3500 | -500 | MAXIMUM | FAIL-LEVEL | 3000 | NO CONFLICT | NO |
| 9997 | 130.0 | ATC | 5000 | 3000 | 2000 | LOWER | FAIL-LEVEL | 0 | UNKNOWN | YES |
| 10004 | 131.0 | ATC | 11000 | 10000 | 1000 | LOWER | UNCLASSIFIED | 0 | NONE | NO |

| ACCESSION NUMBER | ID NUMBER | REPORTER | FLIGHT ALTITUDE | ASSIGNED ALTITUDE | DEVIATION | BOUND | FLIGHT PATTERN | LEVEL DEVIATION | EVASIVE ACTION | MILITARY INVOLVED |
|---|---|---|---|---|---|---|---|---|---|---|
| 10005 | 132.0 | ATC | 14000 | 15000 | -1000 | LOWER | FAIL-MAINTAIN | 0 | ATC | YES |
| 10022 | 133.0 | AIRCREW | 3500 | 4000 | -500 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 10036 | 135.0 | AIRCREW | 10600 | 11000 | -400 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10042 | 136.0 | AIRCREW | 21500 | 21000 | 500 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10047 | 139.0 | AIRCREW | 5000 | 4000 | 1000 | LOWER | FAIL-LEVEL | 5000 | NO CONFLICT | YES |
| 10049 | 140.0 | AIR-ATC | 28700 | 28000 | 700 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10058 | 141.0 | AIRCREW | 16400 | 17000 | -500 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10093 | 144.0 | AIRCREW | 13600 | 13000 | 600 | LOWER | UNCLASSIFIED | 0 | YES | NO |
| 10105 | 145.0 | ATC | 7000 | 6000 | 1000 | MAXIMUM | FAIL-ATTAIN | 7000 | NONE | YES |
| 10115 | 146.0 | AIRCREW | 22300 | 23000 | -700 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10118 | 147.0 | AIRCREW | 5200 | 6000 | -800 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 10120 | 149.0 | AIRCREW | 29000 | 28000 | 1000 | MAXIMUM | FAIL-LEVEL | 29000 | YES | NO |
| 10126 | 150.0 | AIRCREW | 17000 | 18000 | -1000 | LOWER | FAIL-LEVEL | 1 | NO CONFLICT | NO |
| 10132 | 153.0 | AIR-ATC | 3000 | 2000 | 1000 | MAXIMUM | UNCLASSIFIED | 3000 | NO CONFLICT | NO |
| 10134 | 154.0 | ATC | 15800 | 15000 | 800 | LOWER | FAIL-MAINTAIN | 0 | NONE | NO |
| 10223 | 157.0 | AIRCREW | 23350 | 23000 | 350 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10228 | 158.0 | AIRCREW | 9000 | 7000 | 2000 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 10240 | 159.0 | AIRCREW | 4200 | 5000 | -800 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10241 | 160.0 | AIRCREW | 24500 | 25000 | -500 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 10258 | 161.0 | AIRCREW | 10000 | 8000 | 2000 | MAXIMUM | FAIL-ATTAIN | 10000 | NO CONFLICT | NO |
| 10259 | 162.0 | AIRCREW | 6000 | 5000 | 1000 | MAXIMUM | FAIL-LEVEL | 6000 | NO CONFLICT | NO |
| 10274 | 163.0 | AIRCREW | 6000 | 7000 | -1000 | MAXIMUM | FAIL-LEVEL | 6000 | NO CONFLICT | NO |
| 10279 | 164.0 | AIRCREW | 6400 | 7000 | -600 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10293 | 165.0 | ATC | 6500 | 8000 | -1500 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 10300 | 166.0 | ATC | 13000 | 14000 | -1000 | LOWER | UNCLASSIFIED | 0 | NO TIME | YES |
| 10369 | 169.0 | AIRCREW | 33000 | 31000 | 2000 | MAXIMUM | UNCLASSIFIED | 33000 | NO CONFLICT | NO |
| 10376 | 170.0 | AIRCREW | 10000 | 9000 | 1000 | MAXIMUM | FAIL-LEVEL | 10000 | NO CONFLICT | NO |
| 10394 | 172.0 | ATC | 13000 | 12000 | 1000 | MAXIMUM | UNCLASSIFIED | 13000 | NONE | YES |
| 10395 | 173.0 | ATC | 11000 | 12000 | -1000 | LOWER | FAIL-MAINTAIN | 0 | NONE | NO |
| 10411 | 174.0 | ATC | 15300 | 14000 | 1300 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 10419 | 175.0 | AIRCREW | 13900 | 15000 | -1100 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10451 | 178.0 | AIRCREW | 5400 | 5000 | 400 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10454 | 179.0 | ATC | 10400 | 9000 | 1400 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 10470 | 180.0 | AIRCREW | 24300 | 23000 | 1300 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10529 | 184.0 | AIRCREW | 10200 | 9000 | 1200 | LOWER | FAIL-MAINTAIN | 0 | ATC | NO |
| 10531 | 185.0 | AIRCREW | 5500 | 6000 | -500 | MAXIMUM | FAIL-LEVEL | 1 | NO CONFLICT | NO |
| 10573 | 188.0 | AIRCREW | 19200 | 24000 | -4800 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 10574 | 189.0 | AIRCREW | 4500 | 3000 | 1500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10589 | 190.0 | AIRCREW | 12000 | 15000 | -3000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | YES |
| 10616 | 191.0 | ATC | 19600 | 20000 | -400 | LOWER | UNCLASSIFIED | 0 | ATC | YES |
| 10637 | 193.0 | ATC | 10000 | 8000 | 2000 | LOWER | FAIL-LEVEL | 0 | ATC | NO |
| 10655 | 195.0 | AIRCREW | 2600 | 3000 | -400 | LOWER | FAIL-MAINTAIN | 0 | ATC | NO |
| 10656 | 196.0 | AIRCREW | 10200 | 11000 | -800 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 10739 | 201.0 | AIRCREW | 15600 | 16000 | -400 | LOWER | FAIL-LEVEL | 0 | YES | NO |
| 10741 | 202.0 | AIRCREW | 32300 | 31000 | 1300 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | YES |

| ACCESSION NUMBER | ID NUMBER | REPORTER | FLIGHT ALTITUDE | ASSIGNED ALTITUDE | DEVIATION | BOUND | FLIGHT PATTERN | LEVEL DEVIATION | EVASIVE ACTION | MILITARY INVOLVED |
|---|---|---|---|---|---|---|---|---|---|---|
| 10754 | 204.0 | AIRCREW | 5000 | 3000 | 2000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10765 | 205.0 | AIRCREW | 10500 | 10000 | 500 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10767 | 206.0 | ATC | 4800 | 7500 | -2700 | LOWER | FAIL-ATTAIN | 0 | UNKNOWN | NO |
| 10771 | 207.0 | ATC | 5000 | 4000 | 1000 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 10774 | 208.0 | ATC | 8600 | 9000 | -400 | LOWER | FAIL-LEVEL | 0 | ATC | NO |
| 10775 | 209.0 | ATC | 8600 | 8000 | 600 | LOWER | FAIL-LEVEL | 0 | NONE | NO |
| 10785 | 210.0 | AIRCREW | 13400 | 14000 | -600 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10843 | 213.0 | AIRCREW | 13200 | 14000 | -800 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10852 | 215.0 | AIR-ATC | 10000 | 8000 | 2000 | MAXIMUM | FAIL-ATTAIN | 10000 | YES | NO |
| 10866 | 216.0 | ATC | 1600 | 3000 | -1400 | MAXIMUM | FAIL-MAINTAIN | 1600 | NONE | NO |
| 10880 | 217.0 | ATC | 7300 | 9000 | -1700 | LOWER | FAIL-LEVEL | 0 | UNKNOWN | NO |
| 10887 | 219.0 | AIRCREW | 11000 | 10000 | 1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10925 | 222.0 | AIRCREW | 10200 | 11000 | -800 | LOWER | FAIL-LEVEL | 0 | YES | NO |
| 10933 | 223.0 | AIRCREW | 10700 | 10000 | 700 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10939 | 224.0 | AIRCREW | 16000 | 15000 | 1000 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 10955 | 227.0 | AIRCREW | 5800 | 7000 | -1200 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10979 | 229.0 | AIRCREW | 15700 | 18000 | -2300 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 10986 | 230.0 | AIRCREW | 5000 | 5500 | -500 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 10999 | 233.0 | AIRCREW | 6000 | 5000 | 1000 | MAXIMUM | FAIL-LEVEL | 0 | YES | NO |
| 11070 | 237.0 | AIRCREW | 28000 | 29000 | -1000 | MAXIMUM | FAIL-ATTAIN | 28000 | NO CONFLICT | NO |
| 11072 | 238.0 | ATC | 9700 | 9000 | 700 | LOWER | UNCLASSIFIED | 9200 | ATC | NO |
| 11075 | 240.0 | AIRCREW | 12000 | 14000 | -2000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 11080 | 241.0 | AIRCREW | 12500 | 13000 | -500 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 11082 | 242.0 | ATC | 8000 | 9000 | -1000 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | YES |
| 11100 | 243.0 | ATC | 5600 | 5000 | 600 | LOWER | UNCLASSIFIED | 0 | ATC | NO |
| 11101 | 244.0 | ATC | 14500 | 16000 | -1500 | LOWER | FAIL-LEVEL | 0 | UNKNOWN | NO |
| 11105 | 245.0 | AIRCREW | 30000 | 31000 | -1000 | MAXIMUM | FAIL-ATTAIN | 30000 | NO CONFLICT | NO |
| 11129 | 250.1 | ATC | 11700 | 11000 | 700 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 11128 | 250.2 | ATC | 12500 | 12000 | 500 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 11128 | 250.3 | ATC | 16900 | 16000 | 900 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 11130 | 251.0 | AIRCREW | 2000 | 2400 | -400 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 11161 | 252.0 | AIRCREW | 7500 | 7000 | 500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 11193 | 253.0 | AIRCREW | 5500 | 5000 | 500 | MAXIMUM | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 11173 | 254.0 | AIRCREW | 16000 | 14000 | 2000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 11258 | 257.0 | AIRCREW | 6000 | 8000 | -2000 | MAXIMUM | FAIL-MAINTAIN | 6000 | NO CONFLICT | NO |
| 11276 | 259.0 | AIRCREW | 5000 | 4000 | 1000 | MAXIMUM | FAIL-LEVEL | 5000 | NO CONFLICT | NO |
| 11295 | 263.0 | ATC | 8000 | 6000 | 2000 | MAXIMUM | UNCLASSIFIED | 8000 | NO CONFLICT | NO |
| 11302 | 265.0 | AIRCREW | 24000 | 23000 | 1000 | MAXIMUM | FAIL-LEVEL | 24000 | NO CONFLICT | NO |
| 11322 | 266.0 | AIRCREW | 7500 | 9000 | -1500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 11325 | 268.0 | AIRCREW | 8000 | 10000 | -2000 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 11350 | 270.0 | ATC | 10800 | 11000 | -200 | LOWER | UNCLASSIFIED | 0 | ATC | NO |
| 11371 | 272.0 | ATC | 3300 | 5000 | -1700 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 11376 | 275.0 | ATC | 15200 | 16000 | -800 | MAXIMUM | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 11378 | 276.0 | AIRCREW | 6200 | 5000 | 1200 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 11393 | 277.0 | AIRCREW | 4500 | 7000 | -2500 | MAXIMUM | FAIL-ATTAIN | 4500 | NONE | NO |

| ACCESSION NUMBER | ID NUMBER | REPORTER | FLIGHT ALTITUDE | ASSIGNED ALTITUDE | DEVIATION | BOUND | FLIGHT PATTERN | LEVEL DEVIATION | EVASIVE ACTION | MILITARY INVOLVED |
|---|---|---|---|---|---|---|---|---|---|---|
| 11403 | 279.0 | AIRCREW | 22000 | 21000 | 1000 | MAXIMUM | FAIL-LEVEL | 22000 | NONE | NO |
| 11449 | 281.0 | AIRCREW | 8700 | 8000 | 700 | MAXIMUM | FAIL-ATTAIN | 0 | NO CONFLICT | NO |
| 11459 | 282.0 | ATC | 10000 | 9000 | 1000 | LOWER | FAIL-MAINTAIN | 0 | NONE | YES |
| 11465 | 285.0 | AIRCREW | 6100 | 7000 | -900 | MAXIMUM | FAIL-LEVEL | 0 | YES | NO |
| 11487 | 286.0 | AIRCREW | 3500 | 5000 | -1500 | MAXIMUM | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 11502 | 287.0 | AIRCREW | 21600 | 21000 | 600 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 11507 | 288.0 | ATC | 8500 | 9000 | -500 | MAXIMUM | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 11510 | 289.0 | AIRCREW | 6300 | 5000 | 1300 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 11511 | 290.0 | ATC | 5500 | 5000 | 500 | MAXIMUM | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 11541 | 291.0 | ATC | 16000 | 10000 | 6000 | MAXIMUM | FAIL-ATTAIN | 0 | ATC | NO |
| 11556 | 292.0 | AIRCREW | 4500 | 6000 | -1500 | MAXIMUM | FAIL-LEVEL | 4500 | YES | NO |
| 11563 | 294.0 | AIRCREW | 5700 | 5000 | 700 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 11573 | 296.0 | ATC | 10600 | 11000 | -400 | LOWER | UNCLASSIFIED | 0 | ATC | NO |
| 11584 | 297.0 | ATC | 10800 | 12000 | -1200 | LOWER | FAIL-MAINTAIN | 0 | NONE | YES |
| 11603 | 301.2 | ATC | 9000 | 8000 | 1000 | LOWER | FAIL-LEVEL | 9000 | NO CONFLICT | NO |
| 11626 | 305.0 | ATC | 14500 | 14000 | 500 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 11628 | 306.0 | ATC | 5500 | 5000 | 500 | LOWER | UNCLASSIFIED | 0 | ATC | NO |
| 11645 | 309.0 | AIRCREW | 3000 | 4000 | -1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 11650 | 310.0 | AIRCREW | 4000 | 3000 | 1000 | MAXIMUM | UNCLASSIFIED | 4000 | NO TIME | YES |
| 11656 | 311.0 | AIRCREW | 24400 | 25000 | -600 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 11667 | 312.0 | AIRCREW | 9300 | 6000 | 3300 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 11674 | 313.0 | AIRCREW | 6000 | 7000 | -1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 11677 | 316.0 | AIRCREW | 11600 | 11000 | 600 | LOWER | FAIL-MAINTAIN | 0 | ATC | YES |
| 11740 | 321.0 | ATC | 23400 | 23000 | 400 | LOWER | UNCLASSIFIED | 0 | UNKNOWN | NO |
| 11752 | 322.0 | AIRCREW | 19500 | 17000 | 2500 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | YES |
| 11771 | 323.0 | ATC | 15400 | 16000 | -600 | LOWER | UNCLASSIFIED | 0 | UNKNOWN | YES |
| 11776 | 324.0 | AIRCREW | 9000 | 10000 | -1000 | MAXIMUM | FAIL-LEVEL | 9000 | NO CONFLICT | NO |
| 11780 | 326.0 | AIRCREW | 8000 | 10000 | -2000 | MAXIMUM | FAIL-LEVEL | 8000 | NO CONFLICT | NO |
| 11795 | 327.0 | ATC | 4000 | 2500 | 1500 | LOWER | FAIL-MAINTAIN | 0 | NONE | NO |
| 11808 | 329.0 | AIRCREW | 15500 | 16000 | -500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 11844 | 331.0 | ATC | 13600 | 13000 | 600 | MAXIMUM | UNCLASSIFIED | 0 | UNKNOWN | YES |
| 11849 | 332.0 | ATC | 15600 | 15000 | 600 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | YES |
| 11871 | 333.0 | AIRCREW | 13700 | 14000 | -300 | MAXIMUM | FAIL-LEVEL | 13700 | NO CONFLICT | NO |
| 11884 | 335.0 | AIRCREW | 15000 | 10000 | 5000 | MAXIMUM | FAIL-ATTAIN | 15000 | NO CONFLICT | NO |
| 11893 | 337.0 | AIRCREW | 14600 | 14000 | 600 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 11899 | 339.0 | AIRCREW | 28800 | 28000 | 800 | LOWER | FAIL-LEVEL | 28800 | NO CONFLICT | NO |
| 11902 | 341.0 | AIRCREW | 7300 | 7000 | 300 | MAXIMUM | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 11948 | 342.0 | AIRCREW | 17400 | 18000 | -600 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 11962 | 343.0 | AIRCREW | 11000 | 10000 | 1000 | LOWER | FAIL-ATTAIN | 0 | NO CONFLICT | NO |
| 11979 | 344.0 | AIRCREW | 32000 | 33000 | -1000 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 11984 | 345.0 | AIRCREW | 4400 | 4000 | 400 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 12011 | 346.0 | AIRCREW | 28800 | 28000 | 800 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 12029 | 349.0 | AIRCREW | 5900 | 5000 | 900 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 12032 | 350.0 | AIRCREW | 8000 | 9000 | -1000 | MAXIMUM | FAIL-LEVEL | 8000 | NO CONFLICT | NO |
| 12034 | 351.0 | AIRCREW | 13000 | 9000 | 4000 | LOWER | FAIL-ATTAIN | 0 | NO CONFLICT | NO |

| ACCESSION NUMBER | ID NUMBER | REPORTER | FLIGHT ALTITUDE | ASSIGNED ALTITUDE | DEVIATION | BOUND | FLIGHT PATTERN | LEVEL DEVIATION | EVASIVE ACTION | MILITARY INVOLVED |
|---|---|---|---|---|---|---|---|---|---|---|
| 12037 | 352.0 | AIRCREW | 5300 | 6000 | -700 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 12046 | 353.0 | ATC | 1600 | 2600 | -1000 | LOWER | FAIL-LEVEL | 0 | UNKNOWN | NO |
| 12054 | 355.0 | AIRCREW | 2500 | 3000 | -500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 12055 | 356.0 | ATC | 6600 | 7000 | -400 | LOWER | UNCLASSIFIED | 0 | ATC | NO |
| 12077 | 358.0 | AIRCREW | 18000 | 17500 | 500 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 12091 | 360.0 | AIRCREW | 8600 | 10000 | -1400 | LOWER | UNCLASSIFIED | 0 | NONE | NO |
| 12099 | 361.0 | ATC | 8000 | 5000 | 3000 | LOWER | UNCLASSIFIED | 0 | NONE | YES |
| 12135 | 364.0 | AIRCREW | 3700 | 4000 | -300 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 12148 | 367.0 | ATC | 7000 | 5000 | 2000 | LOWER | UNCLASSIFIED | 0 | ATC | NO |
| 12220 | 374.0 | AIRCREW | 6700 | 6000 | 700 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 12221 | 375.0 | AIRCREW | 20000 | 23000 | -3000 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 12222 | 376.2 | AIRCREW | 3400 | 4000 | -600 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 12246 | 379.0 | AIRCREW | 16200 | 17000 | -800 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 12267 | 382.0 | ATC | 2600 | 2000 | 600 | LOWER | UNCLASSIFIED | 2600 | ATC | NO |
| 12276 | 383.0 | ATC | 3300 | 2000 | 1300 | LOWER | FAIL-LEVEL | 3300 | ATC | NO |
| 12310 | 387.0 | AIRCREW | 10000 | 8000 | 2000 | MAXIMUM | FAIL-ATTAIN | 10000 | NO CONFLICT | NO |
| 12322 | 388.0 | AIRCREW | 7000 | 10000 | -3000 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 12330 | 389.0 | ATC | 32200 | 31000 | 1200 | LOWER | FAIL-MAINTAIN | 0 | NONE | NO |
| 12332 | 390.0 | ATC | 3000 | 5000 | -2000 | MAXIMUM | FAIL-ATTAIN | 3000 | ATC | NO |
| 12331 | 391.0 | ATC | 9900 | 11000 | -1100 | MAXIMUM | FAIL-MAINTAIN | 0 | NONE | YES |
| 12357 | 393.0 | ATC | 13400 | 14000 | -600 | MAXIMUM | FAIL-LEVEL | 0 | NONE | NO |
| 12361 | 394.1 | ATC | 1700 | 2000 | -300 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 12361 | 394.2 | ATC | 1000 | 2000 | -1000 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 12369 | 395.0 | ATC | 36600 | 37000 | -400 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 12373 | 396.0 | ATC | 10700 | 10000 | 700 | MAXIMUM | FAIL-LEVEL | 0 | YES | NO |
| 12374 | 397.0 | ATC | 14000 | 13000 | 1000 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 12399 | 398.0 | AIRCREW | 4000 | 4500 | -500 | LOWER | UNCLASSIFIED | 0 | NONE | NO |
| 12405 | 399.0 | AIRCREW | 24000 | 23000 | 1000 | MAXIMUM | FAIL-LEVEL | 24000 | NO CONFLICT | NO |
| 12413 | 401.0 | AIRCREW | 10900 | 10000 | 900 | MAXIMUM | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 12428 | 403.0 | ATC | 9200 | 11000 | -1800 | LOWER | FAIL-MAINTAIN | 0 | ATC | NO |
| 12446 | 406.0 | AIRCREW | 5200 | 4000 | 1200 | MAXIMUM | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 12466 | 407.0 | AIRCREW | 2500 | 3600 | -1100 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 12467 | 408.0 | AIRCREW | 35000 | 33000 | 2000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 12495 | 410.0 | AIRCREW | 7000 | 6000 | 1000 | MAXIMUM | FAIL-LEVEL | 7000 | NO CONFLICT | NO |
| 12515 | 412.0 | AIRCREW | 13500 | 15000 | -1500 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 12551 | 414.0 | ATC | 4600 | 5000 | -400 | LOWER | FAIL-MAINTAIN | 0 | ATC | NO |
| 12553 | 415.0 | ATC | 6000 | 5000 | 1000 | LOWER | FAIL-LEVEL | 0 | UNKNOWN | NO |
| 12566 | 416.0 | AIRCREW | 9500 | 10000 | -500 | MAXIMUM | FAIL-LEVEL | 9500 | NO CONFLICT | NO |
| 12593 | 417.0 | AIRCREW | 10000 | 8000 | 2000 | MAXIMUM | FAIL-ATTAIN | 0 | NO CONFLICT | NO |
| 12516 | 418.0 | AIRCREW | 28500 | 27000 | 1500 | MAXIMUM | FAIL-ATTAIN | 0 | NO CONFLICT | NO |
| 12631 | 419.1 | AIRCREW | 10000 | 11000 | -1000 | MAXIMUM | FAIL-LEVEL | 1000 | NO CONFLICT | NO |
| 12631 | 419.2 | AIRCREW | 2500 | 3500 | -1000 | MAXIMUM | FAIL-LEVEL | 2500 | NO CONFLICT | NO |
| 12651 | 420.0 | AIR-ATC | 10400 | 11000 | -600 | LOWER | FAIL-LEVEL | 0 | YES | NO |
| 12659 | 421.0 | ATC | 10000 | 9000 | 1000 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 12676 | 424.0 | AIR-ATC | 10600 | 10000 | 600 | LOWER | FAIL-LEVEL | 0 | ATC | NO |

| ACCESSION NUMBER | ID NUMBER | REPORTER | FLIGHT ALTITUDE | ASSIGNED ALTITUDE | DEVIATION | BOUND | FLIGHT PATTERN | LEVEL DEVIATION | EVASIVE ACTION | MILITARY INVOLVED |
|---|---|---|---|---|---|---|---|---|---|---|
| 12697 | 426.0 | AIRCREW | 23500 | 24000 | -500 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 12730 | 428.0 | AIRCREW | 12400 | 13000 | -600 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 12736 | 429.0 | ATC | 29000 | 33000 | -4000 | MAXIMUM | FAIL-MAINTAIN | 29000 | NO CONFLICT | NO |
| 12756 | 431.0 | ATC | 5500 | 8000 | -2500 | MAXIMUM | FAIL-MAINTAIN | 0 | UNKNOWN | YES |
| 12763 | 432.1 | ATC | 10300 | 10000 | 300 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 12767 | 433.0 | AIRCREW | 20500 | 21000 | -500 | LOWER | FAIL-LEVEL | 0 | YES | NO |
| 12770 | 434.0 | AIRCREW | 22600 | 22000 | 600 | MAXIMUM | FAIL-LEVEL | 22600 | NO CONFLICT | NO |
| 12772 | 435.0 | AIRCREW | 10000 | 8000 | 2000 | MAXIMUM | FAIL-ATTAIN | 10000 | NO CONFLICT | NO |
| 12779 | 437.0 | AIRCREW | 7000 | 6000 | 1000 | MAXIMUM | FAIL-LEVEL | 7000 | NO CONFLICT | NO |
| 12784 | 438.0 | ATC | 10400 | 11000 | -600 | MAXIMUM | UNCLASSIFIED | 0 | YES | NO |
| 12814 | 439.0 | ATC | 17000 | 18000 | -1000 | LOWER | FAIL-MAINTAIN | 0 | YES | YES |
| 12822 | 440.0 | ATC | 14100 | 13000 | 1100 | LOWER | FAIL-LEVEL | 0 | NO TIME | YES |
| 12888 | 443.0 | AIRCREW | 7300 | 6000 | 1300 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 12911 | 445.0 | AIRCREW | 15000 | 17000 | -2000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 12939 | 448.0 | ATC | 10300 | 11000 | -700 | MAXIMUM | FAIL-LEVEL | 10300 | NO CONFLICT | NO |
| 12956 | 450.0 | AIRCREW | 20400 | 20000 | 400 | MAXIMUM | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 12985 | 451.0 | AIRCREW | 18000 | 16000 | 2000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 12995 | 452.0 | ATC | 4000 | 3000 | 1000 | MAXIMUM | FAIL-LEVEL | 4000 | NO CONFLICT | NO |
| 12997 | 453.0 | AIRCREW | 7000 | 5000 | 2000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 12999 | 455.0 | AIRCREW | 16500 | 16000 | 500 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13004 | 457.0 | AIRCREW | 10700 | 10000 | 700 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13014 | 459.0 | ATC | 7600 | 7000 | 600 | LOWER | FAIL-LEVEL | 0 | ATC | NO |
| 13017 | 460.0 | AIRCREW | 11700 | 10000 | 1700 | MAXIMUM | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 13030 | 462.0 | AIRCREW | 4000 | 4500 | -500 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13060 | 464.0 | ATC | 4700 | 6000 | -1300 | LOWER | FAIL-MAINTAIN | 0 | NO TIME | YES |
| 13077 | 466.0 | AIRCREW | 5500 | 6000 | -500 | LOWER | FAIL-MAINTAIN | 0 | ATC | NO |
| 13126 | 470.0 | AIRCREW | 24000 | 23000 | 1000 | MAXIMUM | FAIL-LEVEL | 24000 | NO CONFLICT | NO |
| 13128 | 471.0 | AIRCREW | 23000 | 24000 | -1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13129 | 472.0 | ATC | 28100 | 29000 | -900 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13291 | 475.0 | AIRCREW | 19500 | 19000 | 500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13294 | 476.0 | ATC | 15000 | 14000 | 1000 | MAXIMUM | FAIL-LEVEL | 15000 | NO CONFLICT | NO |
| 13332 | 477.0 | AIRCREW | 23000 | 24000 | -1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13363 | 478.0 | AIRCREW | 22000 | 21000 | 1000 | MAXIMUM | FAIL-LEVEL | 22000 | YES | NO |
| 13364 | 479.0 | AIR-ATC | 11000 | 10000 | 1000 | MAXIMUM | FAIL-LEVEL | 11000 | NO CONFLICT | NO |
| 13397 | 481.0 | ATC | 25000 | 26000 | -1000 | LOWER | UNCLASSIFIED | 0 | YES | NO |
| 13398 | 482.0 | AIRCREW | 11700 | 7000 | 4700 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13409 | 483.0 | AIRCREW | 7000 | 6000 | 1000 | LOWER | UNCLASSIFIED | 7000 | NO TIME | NO |
| 13421 | 484.0 | AIRCREW | 28000 | 29000 | -1000 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 13471 | 465.0 | AIRCREW | 17000 | 18000 | -1000 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13472 | 486.0 | AIRCREW | 4500 | 6000 | -1500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13488 | 486.0 | AIR-ATC | 10600 | 10000 | 600 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 13499 | 489.0 | ATC | 2000 | 2500 | -500 | LOWER | UNCLASSIFIED | 0 | YES | NO |
| 13525 | 491.0 | ATC | 3000 | 2000 | 1000 | MAXIMUM | FAIL-MAINTAIN | 3000 | ATC | YES |
| 13554 | 493.0 | AIRCREW | 16400 | 17000 | -600 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13572 | 495.0 | ATC | 12000 | 11000 | 1000 | LOWER | FAIL-LEVEL | 12000 | UNKNOWN | YES |

| ACCESSION NUMBER | ID NUMBER | REPORTER | FLIGHT ALTITUDE | ASSIGNED ALTITUDE | DEVIATION | BOUND | FLIGHT PATTERN | LEVEL DEVIATION | EVASIVE ACTION | MILITARY INVOLVED |
|---|---|---|---|---|---|---|---|---|---|---|
| 13603 | 496.0 | AIRCREW | 5800 | 5000 | 800 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13612 | 499.0 | AIRCREW | 5400 | 5000 | 400 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13618 | 500.0 | AIRCREW | 9000 | 10000 | -1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13623 | 503.1 | ATC | 10700 | 10000 | 700 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13623 | 503.2 | ATC | 10300 | 11000 | -700 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13629 | 505.0 | ATC | 4000 | 5000 | -1000 | MAXIMUM | FAIL-ATTAIN | 4000 | NO CONFLICT | NO |
| 13639 | 506.0 | ATC | 5000 | 6000 | -1000 | LOWER | UNCLASSIFIED | 0 | UNKNOWN | YES |
| 13643 | 507.0 | ATC | 2200 | 3500 | -1300 | LOWER | UNCLASSIFIED | 0 | UNKNOWN | NO |
| 13651 | 508.0 | ATC | 5100 | 5000 | 100 | LOWER | FAIL-LEVEL | 0 | ATC | NO |
| 13660 | 510.0 | AIRCREW | 10000 | 11000 | -1000 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 13673 | 511.0 | AIRCREW | 17900 | 17000 | 900 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13678 | 512.0 | AIRCREW | 10500 | 10000 | 500 | LOWER | FAIL-ATTAIN | 0 | NO CONFLICT | NO |
| 13685 | 516.0 | AIRCREW | 6800 | 6500 | 300 | MAXIMUM | FAIL-MAINTAIN | 0 | YES | NO |
| 13727 | 519.0 | AIRCREW | 10000 | 8000 | 2000 | MAXIMUM | FAIL-ATTAIN | 10000 | NO CONFLICT | NO |
| 13733 | 520.0 | AIRCREW | 4300 | 3500 | 800 | MAXIMUM | UNCLASSIFIED | 4300 | NO CONFLICT | NO |
| 13738 | 522.0 | AIRCREW | 5700 | 5000 | 700 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13758 | 524.0 | AIRCREW | 8600 | 10000 | -1400 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13762 | 526.0 | AIRCREW | 10300 | 10000 | 300 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13778 | 528.0 | AIRCREW | 11000 | 8000 | 3000 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 13795 | 529.0 | AIRCREW | 21500 | 23000 | -1500 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13796 | 530.0 | AIR-ATC | 27050 | 29000 | -1950 | MAXIMUM | FAIL-LEVEL | 0 | NO TIME | NO |
| 13807 | 533.0 | AIRCREW | 6000 | 5000 | 1000 | LOWER | FAIL-LEVEL | 6000 | NO CONFLICT | NO |
| 13829 | 537.0 | ATC | 20000 | 19000 | 1000 | LOWER | FAIL-MAINTAIN | 0 | NO TIME | YES |
| 13839 | 540.0 | AIRCREW | 14000 | 18000 | -4000 | MAXIMUM | FAIL-MAINTAIN | 14000 | NO CONFLICT | NO |
| 13842 | 541.0 | ATC | 14000 | 15000 | -1000 | LOWER | FAIL-LEVEL | 0 | NONE | NO |
| 13849 | 543.0 | ATC | 6600 | 6000 | 600 | MAXIMUM | FAIL-LEVEL | 0 | ATC | NO |
| 13871 | 544.0 | ATC | 7000 | 6000 | 1000 | LOWER | FAIL-LEVEL | 0 | UNKNOWN | NO |
| 13880 | 546.0 | AIRCREW | 35500 | 35000 | 500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13881 | 547.0 | AIRCREW | 27600 | 28000 | -400 | MAXIMUM | FAIL-LEVEL | 0 | YES | NO |
| 13886 | 548.0 | AIRCREW | 30300 | 31500 | -1200 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 13889 | 549.0 | AIRCREW | 17500 | 15000 | 2500 | LOWER | UNCLASSIFIED | 0 | ATC | NO |
| 13890 | 550.0 | ATC | 11000 | 10000 | 1000 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13893 | 551.0 | AIRCREW | 24300 | 25000 | -700 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13899 | 552.0 | AIRCREW | 7300 | 6000 | 1300 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13900 | 553.0 | AIRCREW | 22000 | 20000 | 2000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13922 | 554.0 | ATC | 1100 | 1300 | -200 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13941 | 556.0 | AIRCREW | 6500 | 5000 | 1500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13967 | 557.0 | ATC | 11400 | 11000 | 400 | LOWER | FAIL-LEVEL | 0 | ATC | NO |
| 13968 | 558.0 | AIRCREW | 6500 | 5000 | 1500 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13974 | 559.0 | ATC | 11100 | 12000 | -900 | LOWER | UNCLASSIFIED | 0 | ATC | NO |
| 13992 | 560.0 | ATC | 10000 | 11000 | -1000 | MAXIMUM | FAIL-ATTAIN | 10000 | NO CONFLICT | NO |
| 13995 | 562.0 | AIRCREW | 9100 | 10000 | -900 | MAXIMUM | FAIL-LEVEL | 9100 | NO CONFLICT | NO |
| 13997 | 563.0 | AIRCREW | 3000 | 3500 | -500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 13998 | 564.0 | AIRCREW | 13200 | 14000 | -800 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14017 | 567.0 | AIRCREW | 11300 | 10000 | 1300 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |

| ACCESSION NUMBER | ID NUMBER | REPORTER | FLIGHT ALTITUDE | ASSIGNED ALTITUDE | DEVIATION | ROUND | FLIGHT PATTERN | LEVEL DEVIATION | EVASIVE ACTION | MILITARY INVOLVED |
|---|---|---|---|---|---|---|---|---|---|---|
| 14031 | 568.0 | ATC | 12000 | 11000 | 1000 | LOWER | FAIL-LEVEL | 0 | ATC | YES |
| 14071 | 569.0 | ATC | 8100 | 7000 | 1100 | LOWER | FAIL-LEVEL | 0 | NO TIME | YES |
| 14076 | 570.0 | AIRCREW | 16800 | 17000 | -200 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14084 | 571.0 | AIRCREW | 11000 | 15000 | -4000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14088 | 572.0 | AIRCREW | 22700 | 22000 | 700 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14109 | 573.0 | AIRCREW | 7600 | 8000 | -400 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14111 | 574.0 | ATC | 14000 | 15000 | -1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14116 | 576.0 | AIRCREW | 23300 | 23000 | 300 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14117 | 577.0 | AIRCREW | 6800 | 7000 | -200 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 14141 | 579.0 | AIRCREW | 6000 | 10000 | -4000 | MAXIMUM | FAIL-MAINTAIN | 6000 | NO CONFLICT | NO |
| 14262 | 585.0 | ATC | 3500 | 1400 | 2100 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 14266 | 586.0 | ATC | 4000 | 3000 | 1000 | LOWER | UNCLASSIFIED | 0 | YES | NO |
| 14268 | 587.0 | ATC | 28600 | 28000 | 600 | LOWER | UNCLASSIFIED | 0 | YES | NO |
| 14271 | 588.0 | AIRCREW | 32300 | 33000 | -700 | MAXIMUM | FAIL-MAINTAIN | 32300 | NO CONFLICT | NO |
| 14278 | 589.0 | ATC | 29900 | 29000 | 900 | MAXIMUM | FAIL-MAINTAIN | 0 | ATC | NO |
| 14280 | 590.0 | ATC | 3000 | 2000 | 1000 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 14289 | 591.0 | AIRCREW | 14000 | 15000 | -1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14326 | 594.0 | ATC | 2600 | 3000 | -400 | LOWER | UNCLASSIFIED | 0 | YES | NO |
| 14328 | 595.0 | ATC | 7000 | 5000 | 2000 | LOWER | UNCLASSIFIED | 0 | ATC | YES |
| 14340 | 596.0 | AIRCREW | 13000 | 14000 | -1000 | LOWER | FAIL-LEVEL | 13000 | NO CONFLICT | NO |
| 14348 | 598.0 | AIRCREW | 12900 | 12000 | 900 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14355 | 600.0 | AIRCREW | 35600 | 35000 | 600 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14356 | 601.0 | AIRCREW | 32400 | 33000 | -600 | MAXIMUM | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 14365 | 602.0 | ATC | 16500 | 16000 | 500 | LOWER | FAIL-LEVEL | 0 | UNKNOWN | YES |
| 14387 | 605.0 | ATC | 20400 | 20000 | 400 | LOWER | FAIL-MAINTAIN | 0 | ATC | NO |
| 14436 | 606.0 | AIRCREW | 11400 | 13000 | -1600 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14438 | 607.1 | AIRCREW | 8500 | 10000 | -1500 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 14452 | 609.0 | AIRCREW | 3000 | 5000 | -2000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14474 | 610.0 | AIRCREW | 11800 | 10000 | 2200 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 14475 | 611.0 | AIRCREW | 8000 | 6000 | 2000 | LOWER | FAIL-LEVEL | 0 | NONE | NO |
| 14478 | 612.0 | AIRCREW | 1200 | 1900 | -700 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14482 | 614.0 | AIRCREW | 15000 | 14000 | 1000 | MAXIMUM | FAIL-LEVEL | 15000 | NO CONFLICT | NO |
| 14488 | 615.0 | AIRCREW | 5200 | 6000 | -800 | MAXIMUM | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 14493 | 616.0 | AIRCREW | 23000 | 22000 | 1000 | MAXIMUM | FAIL-LEVEL | 23000 | NO CONFLICT | NO |
| 14514 | 617.0 | ATC | 4000 | 5000 | -500 | MAXIMUM | FAIL-LEVEL | 0 | ATC | NO |
| 14529 | 619.0 | AIRCREW | 10000 | 8000 | 2000 | MAXIMUM | FAIL-ATTAIN | 10000 | NO CONFLICT | NO |
| 14533 | 621.0 | AIRCREW | 8600 | 9000 | -400 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14581 | 625.0 | AIRCREW | 10000 | 11000 | -1000 | MAXIMUM | FAIL-MAINTAIN | 10000 | NO CONFLICT | NO |
| 14585 | 626.0 | AIRCREW | 12300 | 13000 | -700 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14598 | 628.0 | AIRCREW | 8200 | 8000 | 200 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 14603 | 629.0 | ATC | 25000 | 24000 | 1000 | LOWER | UNCLASSIFIED | 0 | NONE | NO |
| 14611 | 630.0 | ATC | 2000 | 6000 | -4000 | LOWER | FAIL-MAINTAIN | 0 | ATC | YES |
| 14633 | 631.0 | AIRCREW | 22300 | 23000 | -700 | MAXIMUM | FAIL-LEVEL | 0 | YES | NO |
| 14646 | 634.0 | ATC | 24100 | 24000 | 400 | LOWER | UNCLASSIFIED | 0 | ATC | NO |
| 14720 | 635.0 | AIRCREW | 23000 | 22000 | 1000 | LOWER | FAIL-ATTAIN | 0 | ATC | NO |

| ACCESSION NUMBER | ID NUMBER | REPORTER | FLIGHT ALTITUDE | ASSIGNED ALTITUDE | DEVIATION | BOUND | FLIGHT PATTERN | LEVEL DEVIATION | EVASIVE ACTION | MILITARY INVOLVED |
|---|---|---|---|---|---|---|---|---|---|---|
| 14722 | 637.0 | AIRCREW | 5800 | 6000 | -200 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 14723 | 638.0 | AIRCREW | 10000 | 11000 | -1000 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 14727 | 640.0 | AIRCREW | 7000 | 6000 | 1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14739 | 641.0 | AIRCREW | 2300 | 2700 | -400 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 14762 | 642.0 | AIRCREW | 30200 | 29000 | 1200 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14766 | 643.0 | AIRCREW | 10500 | 13000 | -2500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14768 | 644.0 | AIRCREW | 16000 | 19000 | -3000 | MAXIMUM | FAIL-MAINTAIN | 6000 | NO CONFLICT | NO |
| 14800 | 646.0 | AIR-ATC | 18000 | 19000 | -1000 | LOWER | UNCLASSIFIED | 0 | ATC | NO |
| 14840 | 651.0 | ATC | 33900 | 33000 | 900 | LOWER | UNCLASSIFIED | 0 | ATC | YES |
| 14845 | 654.0 | AIRCREW | 7000 | 11000 | -4000 | MAXIMUM | FAIL-MAINTAIN | 7000 | NO CONFLICT | NO |
| 14847 | 655.0 | AIRCREW | 9600 | 10000 | -400 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14850 | 656.0 | ATC | 10200 | 9000 | 1200 | LOWER | FAIL-LEVEL | 0 | UNKNOWN | NO |
| 14854 | 657.0 | AIRCREW | 6300 | 7000 | -700 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 14857 | 658.0 | AIRCREW | 14000 | 16000 | -2000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14865 | 660.0 | AIRCREW | 29000 | 28000 | 1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14891 | 662.0 | ATC | 22700 | 23000 | -300 | LOWER | FAIL-LEVEL | 0 | ATC | NO |
| 14925 | 666.0 | ATC | 10500 | 5500 | 5000 | LOWER | UNCLASSIFIED | 0 | UNKNOWN | NO |
| 14940 | 667.0 | AIRCREW | 23000 | 22000 | 1000 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 14965 | 670.0 | ATC | 4000 | 3000 | 1000 | LOWER | UNCLASSIFIED | 0 | ATC | NO |
| 14976 | 671.0 | AIRCREW | 19300 | 20000 | -700 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 14988 | 672.0 | AIR-ATC | 23500 | 23000 | 500 | LOWER | UNCLASSIFIED | 0 | UNKNOWN | NO |
| 15001 | 674.0 | AIRCREW | 21400 | 20000 | 1400 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 15015 | 676.0 | ATC | 15500 | 16000 | -500 | LOWER | UNCLASSIFIED | 0 | ATC | NO |
| 15025 | 677.0 | AIR-ATC | 9400 | 12000 | -2600 | LOWER | UNCLASSIFIED | 0 | NO TIME | YES |
| 15042 | 679.1 | AIRCREW | 13000 | 16000 | -3000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 15042 | 679.2 | AIRCREW | 5700 | 6000 | -300 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 15052 | 680.0 | ATC | 35000 | 31000 | 4000 | MAXIMUM | FAIL-ATTAIN | 35000 | ATC | NO |
| 15127 | 688.0 | ATC | 29900 | 29000 | 900 | LOWER | UNCLASSIFIED | 0 | ATC | NO |
| 15133 | 690.0 | AIRCREW | 8000 | 7000 | 1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 15143 | 691.0 | AIRCREW | 21500 | 20000 | 1500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 15150 | 692.0 | ATC | 13500 | 13000 | 500 | LOWER | FAIL-LEVEL | 0 | ATC | YES |
| 15172 | 693.0 | ATC | 4400 | 4000 | 400 | LOWER | UNCLASSIFIED | 0 | ATC | NO |
| 15281 | 695.0 | ATC | 12000 | 11000 | 1000 | LOWER | UNCLASSIFIED | 0 | UNKNOWN | YES |
| 15282 | 696.0 | ATC | 17000 | 16000 | 1000 | LOWER | UNCLASSIFIED | 0 | UNKNOWN | YES |
| 15293 | 697.0 | ATC | 17800 | 21000 | -3200 | LOWER | FAIL-LEVEL | 0 | ATC | YES |
| 15391 | 702.0 | ATC | 3000 | 5000 | -2000 | LOWER | UNCLASSIFIED | 0 | UNKNOWN | NO |
| 15403 | 703.0 | AIR-ATC | 4900 | 3000 | 1900 | LOWER | FAIL-LEVEL | 0 | ATC | NO |
| 15426 | 704.1 | ATC | 5200 | 5000 | 200 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 15426 | 704.2 | ATC | 4900 | 6000 | -1100 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 15430 | 705.0 | AIR-ATC | 20500 | 19000 | 1500 | LOWER | FAIL-LEVEL | 0 | ATC | NO |
| 15529 | 708.0 | AIRCREW | 26000 | 25000 | 1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 15535 | 709.0 | AIRCREW | 10000 | 9000 | 1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 15534 | 710.0 | ATC | 7700 | 7000 | 700 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 15590 | 711.0 | ATC | 5000 | 6000 | -1000 | LOWER | UNCLASSIFIED | 0 | UNKNOWN | NO |
| 15611 | 712.0 | ATC | 19800 | 19000 | 800 | LOWER | FAIL-LEVEL | 0 | UNKNOWN | YES |

| ACCESSION NUMBER | ID NUMBER | REPORTER | FLIGHT ALTITUDE | ASSIGNED ALTITUDE | DEVIATION | BOUND | FLIGHT PATTERN | LEVEL DEVIATION | EVASIVE ACTION | MILITARY INVOLVED |
|---|---|---|---|---|---|---|---|---|---|---|
| 15633 | 714.0 | AIRCREW | 28600 | 29000 | -400 | MAXIMUM | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 15634 | 715.0 | AIRCREW | 1600 | 4000 | -2400 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 15672 | 719.0 | AIRCREW | 12000 | 9000 | 3000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 15727 | 720.0 | AIRCREW | 36000 | 37000 | -1000 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 15798 | 725.0 | ATC | 24000 | 23000 | 1000 | MAXIMUM | FAIL-MAINTAIN | 24000 | YES | YES |
| 15967 | 726.0 | AIRCREW | 5500 | 5000 | 500 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 15869 | 727.1 | AIRCREW | 2500 | 3000 | -500 | MAXIMUM | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 15882 | 728.0 | ATC | 27200 | 28000 | -800 | LOWER | UNCLASSIFIED | 0 | NO TIME | NO |
| 15957 | 730.0 | AIRCREW | 20000 | 21000 | -1000 | LOWER | FAIL-LEVEL | 0 | YES | YES |
| 15972 | 733.0 | ATC | 3000 | 3200 | -200 | LOWER | FAIL-MAINTAIN | 0 | NONE | NO |
| 15987 | 734.0 | AIRCREW | 5600 | 5000 | 600 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 16042 | 735.0 | ATC | 24800 | 23000 | 1800 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | YES |
| 16106 | 736.0 | AIRCREW | 14000 | 16000 | -2000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | YES |
| 16147 | 741.0 | AIRCREW | 5600 | 5000 | 600 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 16148 | 742.0 | AIRCREW | 18000 | 21000 | -3000 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 16193 | 744.0 | ATC | 5000 | 4500 | 500 | MAXIMUM | UNCLASSIFIED | 5000 | YES | YES |
| 16212 | 746.0 | AIRCREW | 20000 | 21000 | -1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 16213 | 747.0 | AIRCREW | 15000 | 12000 | 3000 | MAXIMUM | FAIL-ATTAIN | 15000 | NO CONFLICT | NO |
| 16222 | 749.0 | AIRCREW | 10000 | 11000 | -1000 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 16242 | 750.0 | ATC | 3600 | 9000 | -5400 | LOWER | UNCLASSIFIED | 0 | UNKNOWN | YES |
| 16299 | 757.0 | AIRCREW | 15600 | 15000 | 600 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 16309 | 758.0 | AIRCREW | 5000 | 4000 | 1000 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 16325 | 759.0 | AIRCREW | 10480 | 10000 | 480 | MAXIMUM | FAIL-LEVEL | 0 | YES | NO |
| 16333 | 761.0 | AIRCREW | 32800 | 33000 | -200 | LOWER | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 16350 | 765.0 | ATC | 28000 | 29000 | -1000 | MAXIMUM | FAIL-MAINTAIN | 28000 | UNKNOWN | YES |
| 16373 | 766.0 | ATC | 13000 | 12000 | 1000 | LOWER | FAIL-LEVEL | 0 | UNKNOWN | YES |
| 16384 | 767.0 | ATC | 27300 | 24000 | 2300 | MAXIMUM | UNCLASSIFIED | 0 | ATC | NO |
| 16395 | 768.0 | AIR-ATC | 5700 | 5000 | 700 | LOWER | FAIL-LEVEL | 0 | ATC | NO |
| 16389 | 770.0 | AIRCREW | 5500 | 7000 | -1500 | LOWER | UNCLASSIFIED | 0 | YES | NO |
| 16397 | 771.0 | ATC | 35000 | 37000 | -2000 | MAXIMUM | FAIL-MAINTAIN | 35000 | NO CONFLICT | NO |
| 16427 | 775.0 | ATC | 1100 | 2000 | -900 | LOWER | UNCLASSIFIED | 0 | UNKNOWN | NO |
| 16434 | 776.0 | ATC | 12000 | 11000 | 1000 | LOWER | FAIL-LEVEL | 0 | UNKNOWN | YES |
| 16454 | 778.0 | ATC | 11700 | 12000 | -800 | LOWER | FAIL-MAINTAIN | 0 | NONE | NO |
| 16477 | 779.0 | AIRCREW | 2200 | 4000 | -1800 | MAXIMUM | FAIL-MAINTAIN | 0 | NO CONFLICT | NO |
| 16485 | 780.0 | ATC | 6000 | 3000 | 3000 | MAXIMUM | UNCLASSIFIED | 6000 | NO CONFLICT | NO |
| 16491 | 781.0 | AIRCREW | 16000 | 19000 | -3000 | MAXIMUM | FAIL-MAINTAIN | 16000 | NO CONFLICT | NO |
| 16501 | 782.0 | ATC | 14000 | 15000 | -1000 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 16520 | 783.0 | AIRCREW | 31000 | 29000 | 2000 | LOWER | UNCLASSIFIED | 0 | NO TIME | YES |
| 16525 | 784.0 | ATC | 11000 | 10000 | 1000 | MAXIMUM | UNCLASSIFIED | 11000 | ATC | NO |
| 16544 | 785.0 | ATC | 2700 | 2000 | 700 | LOWER | UNCLASSIFIED | 0 | ATC | YES |
| 16613 | 787.0 | ATC | 18300 | 19000 | -700 | LOWER | UNCLASSIFIED | 0 | ATC | YES |
| 16627 | 788.0 | ATC | 1500 | 3000 | -1500 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 16646 | 789.0 | ATC | 23000 | 24000 | -1000 | LOWER | FAIL-LEVEL | 0 | ATC | NO |
| 16651 | 791.0 | ATC | 5400 | 6000 | -600 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 16684 | 793.0 | ATC | 10700 | 10000 | 700 | MAXIMUM | UNCLASSIFIED | 10300 | ATC | NO |

| ACCESSION NUMBER | ID NUMBER | REPORTER | FLIGHT ALTITUDE | ASSIGNED ALTITUDE | DEVIATION | BOUND | FLIGHT PATTERN | LEVEL DEVIATION | EVASIVE ACTION | MILITARY INVOLVED |
|---|---|---|---|---|---|---|---|---|---|---|
| 16589 | 795.0 | AIRCREW | 13000 | 14000 | -1000 | MAXIMUM | FAIL-LEVEL | 13000 | NO CONFLICT | NO |
| 16592 | 796.0 | ATC | 8000 | 5000 | 3000 | LOWER | UNCLASSIFIED | 0 | NO CONFLICT | NO |
| 16693 | 797.0 | ATC | 5900 | 5000 | 900 | LOWER | FAIL-LEVEL | 0 | UNKNOWN | YES |
| 16738 | 800.0 | ATC | 5700 | 5000 | 700 | LOWER | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 16743 | 801.0 | AIRCREW | 10500 | 10000 | 500 | MAXIMUM | FAIL-LEVEL | 0 | NO CONFLICT | NO |
| 15759 | 802.0 | ATC | 6000 | 7000 | -1000 | LOWER | UNCLASSIFIED | 0 | UNKNOWN | NO |
| 16770 | 803.0 | ATC | 12000 | 11000 | 1000 | MAXIMUM | UNCLASSIFIED | 12000 | ATC | YES |
| 16851 | 805.0 | ATC | 35000 | 33000 | 2000 | LOWER | UNCLASSIFIED | 0 | ATC | YES |

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| [redacted] | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
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| | 6. Performing Organization Code |
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15. Supplementary Notes

16. Abstract

This is a statistical study of the magnitudes of altitude deviations obtained from 502 ASRS reports received between May, 1978 and November, 1979. The deviations range from 100 to 16,500 ft. The magnitudes of altitude deviations, without regard to sign, are found to be exponentially distributed with a mean of 1080 ft. Exponential distributions are also found for various subgroups of the reports that include: failures-to-level in which pilots fail to level at assigned altitudes; failures-to-maintain assigned altitudes, including premature departures; and failures-to-attain assigned altitudes, including failures to meet crossing restrictions. These subgroups show mean altitude deviations of 770, 1240, and 1960 ft, respectively. At a constant reference rate of climb or descent, these results are interpreted as exponential distributions of times required for human detection of altitude deviations. On this basis, at an assumed reference rate of 1500 ft/min, it is computed that, half of the time, an altitude deviation would be detected within 30 seconds. Corresponding half-lives of altitude deviations involving failures-to-level, failures-to-maintain, and failures-to-attain are found to be approximately 20, 35, and 55 seconds, respectively. A change in the reference rate of climb or descent yields a change in the mean detection time, but does not change the exponential form of the distribution of detection times.

| 17. Key Words (Suggested by Author(s)) | 18. Distribution Statement |
|---|---|
| Aviation Safety<br>Altitude Deviations<br>Probability Distribution<br>Detection Time | Unlimited |

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